BENTHIC TMDL REPORTS

FOR SIX IMPAIRED STREAM SEGMENTS IN THE POTOMAC-SHENANDOAH AND JAMES RIVER BASINS

Submitted by

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EXECUTIVE SUMMARY

Six stream segments located in the western part of Virginia were designated impaired for not meeting the state's aquatic life use and were included in the Year 1998 303(d) list of impaired waters. In accordance with the Clean Water Act, a total maximum daily load (TMDL) is required for each of these impaired streams. A TMDL is the greatest amount of a pollutant that a waterbody can receive without violating applicable water quality standards. The TMDL consists of a point source wasteload allocation (WLA), a nonpoint source load allocation (LA), and a margin of safety (MOS).

The stream segments considered in this TMDL report are short (0.02-0.8 miles) and the areas for the impaired watersheds range from 10 acres (the smallest) to over 1,400 acres (the largest). The headwaters of the streams are springs. Three of the impaired segments are located in the Potomac and Shenandoah River Basin, and three are located in the James River Basin.

Stream Segment	**Impairment**	**Watershed & ID**	**HUC**
Cockran Spring Branch (Cale Spring Stream) (0.80 miles)	benthic	Potomac & Shenandoah (VAV-B10R)	02070005
Lacey Spring Branch (0.20 miles)	benthic	Potomac & Shenandoah (VAV-B47R)	02070006
Orndorff Spring Branch (0.15 miles)	benthic	Potomac & Shenandoah (VAV-B52R)	02070006
Pheasanty Run (Spring Run) (0.43 miles)	benthic	James River (VAV-I14R)	02080201
Wallace Mill Stream (Casta Line Spring Branch) (0.80 miles)	benthic	James River (VAV-I32R)	02080202
Montebello Spring Branch (0.02 miles)	benthic	James River (VAV-H09R)	02080203

The streams were listed impaired based on benthic macroinvertebrate surveys conducted in 1995 and 1996 using Rapid Biological Assessment Protocol II. Similar results were obtained in 2001 using five replicate Hess samples collected at each site and identifying the macroinvertebrates to genus level. Based on the results of the 2001 benthic surveys, all of the streams are still impaired. Because Virginia does not currently have water quality criteria for benthics, the critical stressor(s) needed to be identified. TMDLs were developed for the identified stressor.

Stressor Identification

The goal of stressor identification is to determine which stressors have resulted in the observed shift in the benthic macroinvertebrate community. Each of the impaired streams receives effluent from a trout facility, and this effluent was suspected as the cause of the impairment. However, the exact pollutant or pollution causing the impairment was not identified. A list of candidate causes was developed from the benthic macroinvertebrate survey reports, published literature, visual surveys, and stakeholder input.

An advisory panel, composed of experts in the field, weighed the evidence, eliminated some stressors from consideration, and identified the most probable stressors based on their best professional judgment. The advisory panel eliminated ammonia, dissolved oxygen, pH, and water temperature from consideration as critical stressors in these six impaired stream segments. Although toxic chemicals, excess nutrients, dissolved organic carbon, and fish predation could not be eliminated as likely stressors, they were judged not to be the most probable stressors. Organic solids and hydraulic alterations were considered the most critical stressors.

Organic solids were identified as the critical stressor in all six impaired streams based on 1) the benthic monitoring results in the impaired segments, 2) a literature review of the effects of organic solids on benthic macroinvertebrate communities, 3) visual observations of accumulated solids in the trout farm raceways and the listed stream segments, and 4) data collected for the TMDL report. TMDLs were therefore calculated for organic solids in each of the impaired streams.

Low flow resulting in long-term dry conditions or inadequate water in Montebello Spring Branch is considered a critical benthic stressor. The advisory panel concluded that that under natural drought conditions, Montebello Springs cannot produce enough water to sustain aquatic life in Montebello Spring Branch so did not recommend that a minimal hydraulic load be maintained in Montebello Spring Branch. DEQ and EPA, however, will need to review the situation.

Existing Loads

For natural background loads from the headwaters—the springs—average total concentrations of total suspended solids (TSS) and flow from the spring obtained during the TMDL study were used to calculate a total solids load. An estimated five percent organic content for the solids in the spring was multiplied by the total solids load to give the organic solids load for the spring. A five percent organic content was used because organic solids from the springs in this study most likely originate from nonpoint source runoff, and five percent was the estimated organic content for the nonpoint sources.

For the trout farms, the organic solids load was estimated from the monitoring that took place during the TMDL study. Average TSS concentrations of effluent samples collected at the farm outfall and average flow measured during the study were used to estimate the total solids load from each trout farm. The resulting TSS load was converted to organic solids load by multiplying the TSS load by the estimated volatile solids fraction. This fraction, 60 percent, was obtained from solids collected from the bottom of settling basins from three of the studied trout farms and was supported by published literature.

Only one other point source was identified in the studied watersheds. Effluent from the sewage treatment of an elementary school enters a drainage ditch that flows for about a half mile to one of the impaired streams, Lacey Springs Branch. The annual total solids load was calculated using the permit flow and average permitted limit of TSS. The organic solids load was estimated by multiplying the TSS load by the average content of domestic sewage, 70 percent.

For nonpoint sources, sediment loads in the affected stream riparian zone were estimated using the Revised Universal Soil Loss Equation (RUSLE) and a sediment delivery ratio of 0.9. The riparian zone was defined as a 300-foot land strip on each side of the stream segment. The RUSLE takes into account the vegetative cover, best management practices, slope, soil erodibility, and amount and intensity of rainfall. These factors are each assigned a numeric value, and the product of these values is multiplied by the riparian land acreage to determine an annual sediment load.

The estimated nonpoint source (NPS) sediment load was converted to the organic solid load by multiplying the NPS sediment load by the percent organic matter content of soil. The soils for the areas under study are naturally 2.5 percent organic (from soil surveys). An organic content higher than this was used in the TMDL calculations to account for contributions from runoff containing organic matter picked up on the surface (e.g., manure). Five percent organic matter content was used for the nonpoint sources.

TMDL Calculations

Virginia does not have a criterion for organic solids so a reference watershed approach was used. The load of organic solids in the reference stream was estimated and used to set the endpoint. Ingleside Spring Branch is the reference stream for the organic solids target for all six impaired streams. Like the impaired streams, Ingleside Spring Branch is a spring-fed stream. A viable benthic community is attained at Ingleside Spring Branch, and in comparison to the impaired stream segments, Ingleside Spring Branch has a lower organic solids load when corrected for area. A viable benthic community should therefore be possible for the impaired sites if their current organic load is reduced below the level in Ingleside Spring Branch.

Owing to differences in the stream lengths between the impaired segment and the reference stream, the target load estimate was adjusted to compensate for differences between the riparian area of the impaired streams and Ingleside Spring Branch. This adjustment was necessary because riparian size influences sediment delivery, and consequently organic solids load, to the stream.

By comparing the impaired streams to a similar non-impaired watershed (Ingleside Spring Branch), the amount of organic solids loading that will meet the water quality objectives was determined. When this value is met, the aquatic life use should be met. Table ES.1 shows the TMDLs for the streams in this study. The WLA portion of the TMDL equation is the total loading assigned to point sources. The LA portion represents the loading assigned to nonpoint sources and includes the headwaters. The MOS is the portion of loading reserved to account for any uncertainty in the data and the computational methodology used for the analysis. An explicit MOS of five percent was used in the TMDL calculations to provide an additional level of protection for aquatic life.

Table ES.1. TMDLs for six impaired stream segments in the Potomac/Shenandoah River and James River Basins.

Watershed	Pollutant	TMDL (pounds/yr)	WLA (pounds/yr)	LA (pounds/yr)	MOS (pounds/yr)
Cockran Spring Branch	Organic Solids	2016	1556	359	101
Lacey Spring Branch	Organic Solids	957	680	229	48
Orndorff Spring Branch	Organic Solids	127	103	17	7
Pheasanty Run	Organic Solids	1582	1231	271	80
Wallace Mill Stream	Organic Solids	3451	2839	439	173
Montebello Spring Branch	Organic Solids	141	37	97	7

Load Allocations and Reductions

Load allocations were assigned to each source category in the watershed based on information from a visual survey, knowledge of best management practices, and professional judgment. Because the spring loading represents the natural condition that would be expected to exist, the loading from the spring was generally not reduced (the spring on Lacey Spring Branch is the one exception).

Critical Environmental Conditions

A TMDL must consider critical environmental conditions for stream flow, loadings, and water quality parameters—that is, the most environmentally stressful times that may occur at the site. The purpose is to ensure that water quality is protected even during the most stressful times. It is necessary therefore to determine how the identified critical stressors may impact the benthic macroinvertebrate community during critical environmental conditions.

Literature indicates that the stress on stream benthic organisms from aquaculture effluent is greatest during periods of high temperatures in association with low flows. To address the critical water quality periods, therefore, water sampling for the TMDL study was conducted during the summer months when water temperatures should be highest and stream flows most likely to be lowest. Loadings from nonpoint sources are expected to be highest following precipitation events, when runoff is highest and the stream carries more sediment. Higher loads from nonpoint sources that occur after precipitation events are included in the nonpoint source estimates calculated from the RUSLE.

Consideration of Seasonal Variations

Summer and winter water monitoring of physical/chemical parameters was conducted to incorporate seasonal variations in the decision making process. The seasonality was also addressed for estimating point and nonpoint source loads. For the trout farms (point sources), seasonality was incorporated in terms of the amount of feed provided at different times of the year. Discharge-permit data were reviewed and used as a guide for expected annual loads. For the nonpoint source determination, seasonality was incorporated in the calculation of the C and R parameters of the RUSLE.

Margin of Safety

In the TMDL reports, an explicit margin of safety (MOS) of five percent was used: the target annual organic solids load was obtained by subtracting five percent of the load from the reference condition.

Reasonable Assurance of Implementation

An adaptive management approach is recommended. Under this approach, the trout farm operators would implement a series of solids management practices. Other point source and nonpoint source management practices should be put in place where applicable. Follow-up monitoring of organic and solid concentrations (and loads) in farm effluents and the listed segments would be used to estimate load reductions. Annual benthic monitoring by DEQ can provide the necessary information about changes to the benthic macroinvertebrate community.

The suggested Best Management Practices (BMPs) that are outlined should be sufficient to reduce the needed organic solids load to the TMDL target. The developed implementation plans should consider all BMPs and utilize the combination that works best for the specific impaired stream section. Installing or redesigning sediment traps and settling basins, more frequent cleanings, and off-line settling basins or land application of solids were recommended as general suggestions for the trout farms. Vegetative buffer strips of shrubs and trees were recommended to reduce nonpoint sources of organic solids load. These buffers should be planted along identified stream segments. Because several of the impaired segments flow through pastures where livestock have direct access to the stream, fences were recommended along these stream segments to reduce the direct disposition of manure (high in organic matter) into the stream.

Public Participation

Two public meetings were held so that local stakeholders, DEQ and DCR personnel, and the TMDL team could discuss openly and as a group the TMDL goals, challenges, and means by which to meet the goals. Input from stakeholders was received at these meetings. A survey questionnaire was mailed to the manager or owner of each of the trout facilities located on the impaired streams, and all the farms participated by returning a completed survey. The survey asked about the spring flow and impaired segment, and about the facility's activities (including feeding and solids removal) as well as trout production. Responses from facility personnel were used in the decision making process and in the development of the TMDL report.

1 INTRODUCTION

1.1 BACKGROUND

1.1.1 TMDL Definition and Regulatory Information

Section 303(d) of the Clean Water Act and EPA's Water Quality Management and Planning Regulation (40 CFR Part 130) require states to develop total maximum daily loads (TMDLs) for an impaired waterbody. A TMDL is the greatest amount of a pollutant that a waterbody can receive without violating applicable water quality standards. Background, point source, and nonpoint source loadings are considered. A fraction of the allowable load is reserved for a margin of safety (MOS) to account for uncertainty, variability, and future development. Through the TMDL process, states can establish water-quality based controls to reduce pollution and restore the quality of their water resources (EPA 1991). A TMDL should set bounds for long-term, sustainable watershed management.

The TMDL consists of a point source wasteload allocation (WLA), a nonpoint source load allocation (LA), and a margin of safety (MOS). The TMDL equation is as follows:

TMDL = WLA + LA + MOS

The WLA portion of this equation is the total loading assigned to point sources. For example, each of the six impaired streams described in this document receive effluent from a trout production facility. The LA portion represents the loading assigned to nonpoint sources. The MOS is the portion of loading reserved to account for any uncertainty in the data and the computational methodology used for the analysis.

1.1.2 Impairment Listing

States are required by the Clean Water Act to identify and report to the U.S. Environmental Protection Agency (EPA) their water quality-impaired waters. Based on benthic macroinvertebrate surveys using Rapid Biological Assessment Protocol II (RBP II), the Virginia Department of Environmental Quality (DEQ) included six stream segments in the Year 1998 303(d) impaired waters list that are located immediately below the discharge point of aquaculture facilities (trout farms). All six segments received a priority listing of medium.

1.1.3 Watershed Locations

Three of the impaired segments are located in the Potomac and Shenandoah River Basin, and three are located in the James River Basin (Figure 1.1). The waters in both basins eventually drain to the Chesapeake Bay. Specific information about each impaired stream's watershed is provided in the section for that stream.

Stream Segment	Impairment	Watershed & ID	HUC
Cockran Spring Branch (Cale Spring Stream) (0.80 miles)	benthic	Potomac & Shenandoah (VAV-B10R)	02070005
Lacey Spring Branch (0.20 miles)	benthic	Potomac & Shenandoah (VAV-B47R)	02070006
Orndorff Spring Branch (0.15 miles)	benthic	Potomac & Shenandoah (VAV-B52R)	02070006
Pheasanty Run (Spring Run) (0.43 miles)	benthic	James River (VAV-I14R)	02080201
Wallace Mill Stream (Casta Line Spring Branch) (0.80 miles)	benthic	James River (VAV-I32R)	02080202
Montebello Spring Branch (0.02 miles)	benthic	James River (VAV-H09R)	02080203

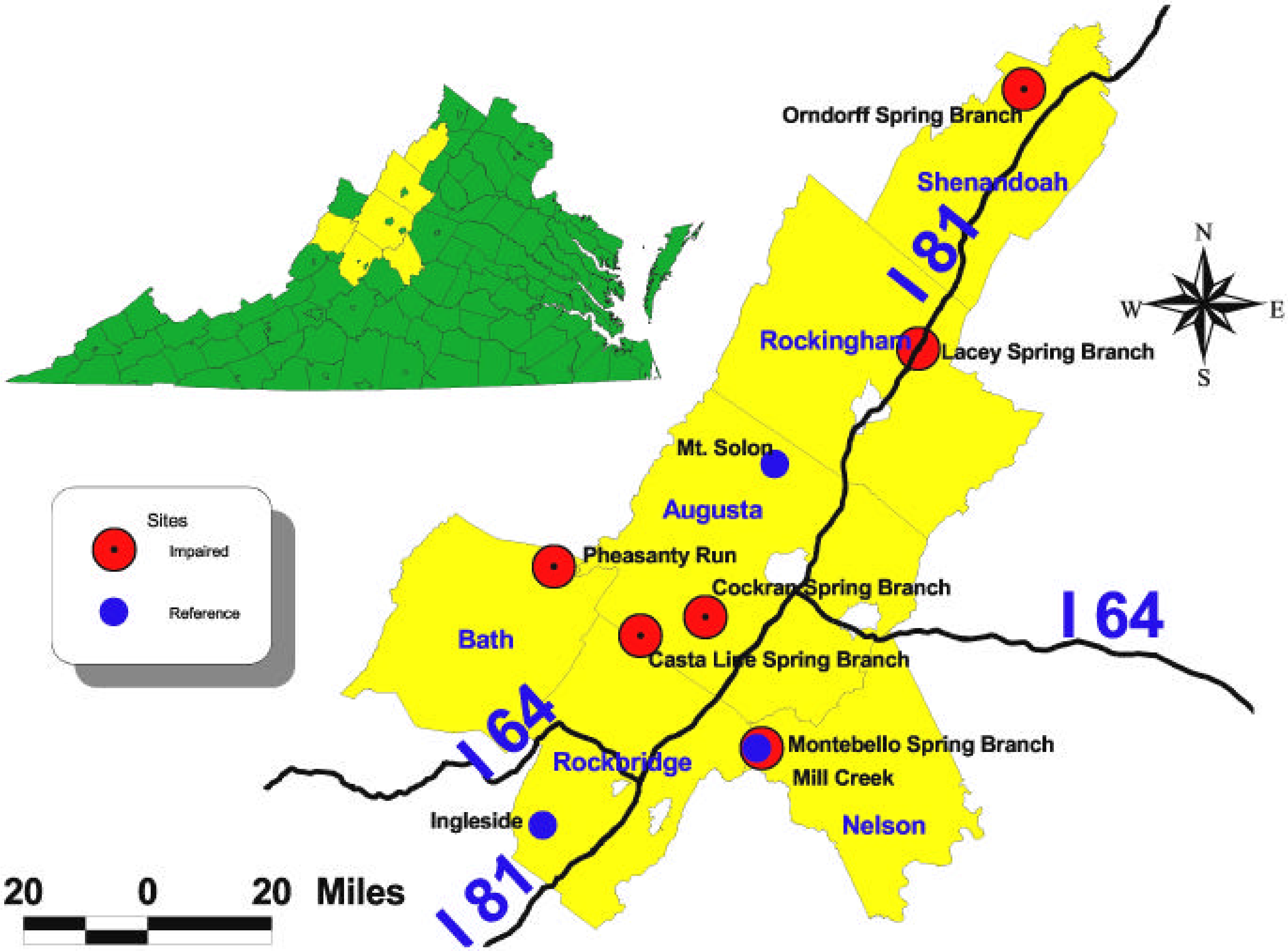


Figure 1.1 Area map showing locations of impaired streams and reference streams.

1.2 DESIGNATED USES AND APPLICABLE WATER QUALITY STANDARDS

1.2.1 Designation of Uses

All state waters, including wetlands, are designated for the following uses: recreational uses, e.g., swimming and boating; the propagation and growth of a balanced, indigenous population of aquatic life, including game fish, which might reasonably be expected to inhabit them; wildlife; and the protection of edible and marketable natural resources, e.g., fish and shellfish (9 VAC 25-260-10).

1.2.2 Water Quality Standards

The water quality criterion utilized to protect the aquatic life designated use is a general narrative statement:

> All state waters, including wetlands, shall be free from substances attributable to sewage, industrial waste, or other waste in concentrations, amounts, or combinations which contravene established standards or interfere directly or indirectly with designated uses of such water or which are inimical or harmful to human, animal, plant, or aquatic life (9 VAC 25-260-20).

1.3 BIOMONITORING ASSESSMENT

Virginia DEQ uses the U.S. EPA approved standardized method, Rapid Biological Assessment Protocol II, to determine if a water body meets the water quality criterion to protect the aquatic life use. EPA and DEQ are working together to develop an Index of Biotic Integrity and regional reference conditions to streamline the assessment process.

Three reference streams were used by DEQ to list the six impaired streams: Ingleside Spring Branch, Mount Solon Spring Branch, and Mill Creek (Table 1.1). Ingleside Spring Branch and Mount Solon Spring Branch are spring-fed streams located in the same ecoregion as their corresponding impaired streams and have the same flow classification as determined by the DEQ aquatic biologists (small or large). Mill Creek is simply the best available site that has thus far been located for Montebello Spring Branch. No spring-fed streams of similar watershed size and other characteristics have been located in the Blue Ridge Mountain ecoregion.

Table 1.1 Impaired streams and their DEQ identified benthic monitoring reference stream, ecoregion classification, and flow classification.

Impaired Stream	Reference Stream	Ecoregion	Flow
Cockran Spring Branch	Mount Solon Spring Branch	Central Appalachian Ridge and Valley	Large
Lacey Spring Branch	Mount Solon Spring Branch	Central Appalachian Ridge and Valley	Large
Orndorff Spring Branch	Ingleside Spring Branch	Central Appalachian Ridge and Valley	Small
Pheasanty Run	Mount Solon Spring Branch	Central Appalachian Ridge and Valley	Large
Wallace Mill Stream	Ingleside Spring Branch	Central Appalachian Ridge and Valley	Small
Montebello Spring Branch	Mill Creek	Blue Ridge Mountains	Small

1.4 TMDL APPROACH

A TMDL was calculated for each of the six impaired segments. The submitted report was written to demonstrate that the following eight regulatory conditions pursuant to 40 CFR Part 130 were met:

1) The TMDLs are designed to implement applicable water quality standards.
2) The TMDLs include a total allowable load as well as individual waste load allocations and load allocations.
3) The TMDLs consider the impacts of background pollutant contributions.
4) The TMDLs consider critical environmental conditions.
5) The TMDLs consider seasonal environmental variations.
6) The TMDLs include a margin of safety.
7) There is reasonable assurance that the TMDLs can be met.
8) The TMDLs have been subject to public participation.

2 BENTHIC TMDL ENDPOINT DETERMINATION

2.1 REFERENCE WATERSHED APPROACH

Virginia does not currently have water quality criteria for benthics. Critical stressors that affect the benthic macroinvertebrate community were identified (See Section 3), and a reference watershed approach was used to identify the TMDL target load for the stressor. By comparing a similar non-impaired watershed to the impaired watershed, the loading that achieves the desired water quality (including a margin of safety) was calculated. When this value is met, the impaired stream is expected to meet its aquatic life use.

2.2 WATERSHED CHARACTERIZATION

The water sources or headwaters for the impaired streams are springs. The geologic formation from which a spring emerges influences its water chemistry and natural water quality. The total dissolved solids (TDS) of groundwater is primarily influenced by the differing geologic formations through which it flows. Similarly, the alkalinity (the ability to neutralize acids) and hardness (the amount of calcium and magnesium) of water is strongly influenced by the geologic formations of the area. Therefore, TDS, alkalinity, and hardness are used as indicators of similarities and differences between the water chemistries of springs.

Five of the impaired streams are located in the Central Appalachian Ridge and Valley ecoregion, limestone subregion (Cockran Spring Branch, Lacey Spring Branch, Orndorff Spring Branch, Pheasanty Run, Wallace Mill Stream). Regions with limestone formations have high TDS, alkalinity, and hardness concentrations. One stream, Montebello Spring Branch, is located in the Blue Ridge Mountains ecoregion and is characterized by low TDS, alkalinity, and hardness concentrations.

Table 2.1 shows the water chemistry for each impaired segment and its benthic macroinvertebrate reference stream along with its watershed size. The TDS, alkalinity, and hardness averages (mg/L) of four to nine water samples collected from July 2001-February 2002 for each headwater and its reference stream are listed in Table 2.1. The headwaters of Montebello Spring Branch are a combination of water from several (primarily two) springs and water pumped from Mill Creek. The water from Mill Creek is added to the spring to provide enough flow for trout production during dry periods, and all the water samples for this TMDL report were collected during a dry period. The majority of water (98 percent) in the impaired section of Pheasanty Run originates from a spring (Coursey Spring). The other portion (2 percent) originates in a forested region upstream of the trout cultural facility. The headwaters for the other impaired streams consist only of spring water. The water samples for the reference streams were taken near the benthic macroinvertebrate sampling location.

Table 2.1 Total dissolved solids (TDS), alkalinity (Alk), hardness, and watershed area for the headwaters of impaired streams and the benthic sampling site of reference streams.

Impaired	Area (acres)	Spring TDS (mg/L)	Spring Alk (mg/L)	Spring Hardness (mg/L)	Reference	Area (acres)	TDS (mg/L)	Alk (mg/L)	Hardness (mg/L)
Cockran Spring	939	219	183	183	Ingleside Mt. Solon	50 222	203 127	143 78	162 96
Lacey Spring	336	365	227	339	Mt. Solon	222	127	78	96
Orndorff Spring	8	180	134	147	Ingleside	50	203	143	162
Pheasanty Run	1322	138	86	103	Mt. Solon	222	127	78	96
Wallace Mill	1454	131	97	106	Ingleside	50	203	143	162
Montebello	291	11	4	4	Mill Creek	1301	10	4	3

Comparisons of the TDS, alkalinity, and hardness data in Table 2.1 show the following:

Cockran Spring Branch has two possible reference sites–Cockran Spring Branch *is* compatible with Ingleside Spring Branch in terms of water chemistry but *is not* compatible with Mount Solon Spring Branch in terms of water chemistry.

Lacey Spring Branch *is not* compatible with its reference stream, Mount Solon Spring Branch, in terms of water chemistry.

Orndorff Spring Branch *is* compatible with its reference stream, Ingleside Spring Branch, in terms of water chemistry.

Pheasanty Run *is* compatible with its reference stream, Mount Solon Spring Branch, in terms of water chemistry.

Wallace Mill Stream *is not* compatible with its reference stream, Ingleside Spring Branch, in terms of water chemistry.

Montebello Spring Branch *is* compatible with its reference stream, Mill Creek, in terms of water chemistry.

There are other dissimilarities between the reference streams and the impaired streams. Differences between the watershed sizes of the impaired streams and the reference sites are evident (Table 2.1). Additionally, the flow differs in some cases: Mill Creek has a flow more than twice that of Montebello Spring Branch, and Mount Solon Spring Branch is less than half the flow of Pheasanty Run. For these reasons and others, the TMDL team, DEQ personnel, and local stakeholders sought additional reference sites, but we were not able to locate a minimally influenced reference site with compatible water chemistry and watershed characteristics.

3 STRESSOR IDENTIFICATION

With benthic degradations, a linkage between cause (water quality or stressor) and effect (benthic condition) is needed, particularly because degradation can be a symptom of multiple stressor effects. Regression analysis can be used to develop such a relationship between stressors and the benthic community. Researchers have attempted to develop general relationships using available data, but results for these studies are either inconclusive or indicate high uncertainty in relationship (Frondorf 2001, Jones 2001).

For this TMDL report, sufficient bioassessment and water quality data were not available to allow using the regression analysis method to establish a statistically valid linkage between stressors and benthic condition. For each impaired stream segment, background information and professional judgment were used to identify critical stressors in the impaired streams. The goal of stressor identification is to determine which stressors have resulted in an observed shift in the benthic macroinvertebrate community. TMDL calculations were developed for the identified critical stressor.

3.1 STRESSOR IDENTIFICATION PROCESS

The process outlined in the EPA's *Stressor Identification Guidance Document* (EPA 2000) was used in the identification of critical stressors for the TMDL reports in this study. A list of candidate causes was developed from the benthic macroinvertebrate survey reports, published literature, visual surveys, and stakeholder input. Chemical analyses of collected water samples provided additional evidence to support or eliminate the potential candidate causes. From this information, the probable stressors and their probable sources were identified. An advisory panel, composed of experts in the field, weighed the evidence, eliminated some stressors from consideration, and identified the most probable stressors based on their best professional judgment.

A conceptual model of the identified likely stressors, their sources, and the means by which they impact the benthic community was developed (Figure 3.1).

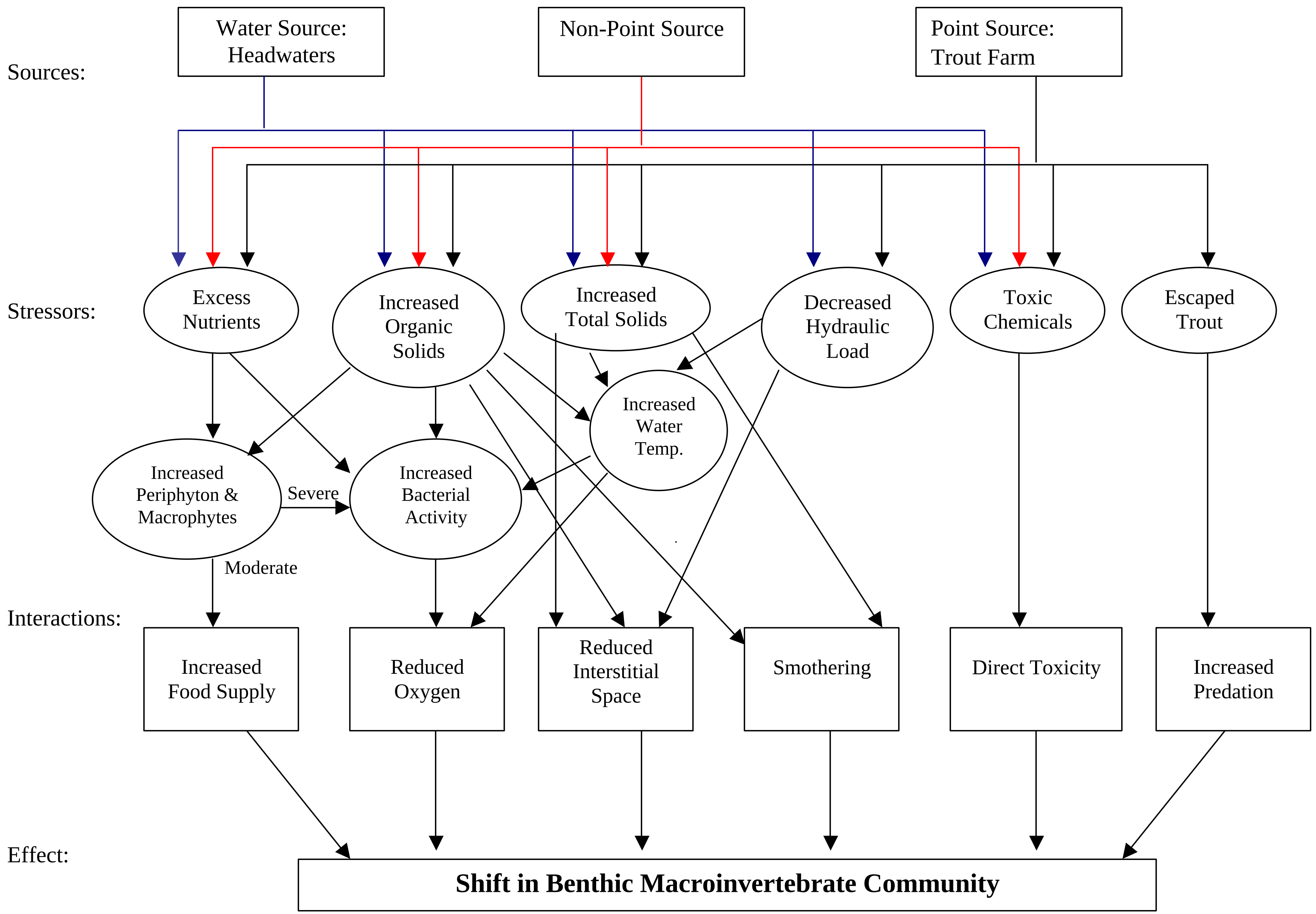


Figure 3.1 Conceptual model showing the potential impact of stressors on the benthic macroinvertebrate community.

3.2 CANDIDATE STRESSORS

Based on the initial evidence provided, the following possible stressors were identified: excess nutrients, organic enrichment, low dissolved oxygen levels, increased solids, toxic chemicals, hydraulic alterations, changes in pH, increased water temperatures, and fish predation.

3.2.1 Sources of Information About Candidate Stressors

Information used to list the candidate stressors included benthic survey reports, published literature, permit requirements, visual surveys, and stakeholder input.

3.2.1.1 Benthic Survey Reports

The DEQ benthic macroinvertebrate monitoring using RBP II in 1995, 1996, and 2000 indicated nutrient enriched waters. "Tolerant" species, those that are tolerant of poor water conditions (e.g., low oxygen levels and heavy sediment loads) occurred most often in the samples. Isopods (sow bugs) and chironomids (midges), which are common in nutrient enriched waters, consistently dominated within five of the impaired streams. In the sixth stream, Montebello Spring Branch, the 1995 sampling found over 85 percent of the counted organisms to be oligochaetes (tubifex worms), which are classic indicator organisms of organic pollution.

The benthic monitoring in 2001, also suggested that all six of the impaired stream segments are enriched (Appendix A). The evidence was indicated primarily by a numerical dominance of taxa such as oligochaetes, isopods and planaria, taxa that are tolerant of poor water and habitat quality. Although these taxa are expected to occur in spring-fed streams, their relative abundance typically was greater than expected for unenriched streams.

3.2.1.2 Published Literature

Studies of the effects of trout farms on receiving waters in Europe, South Africa, and the United States have generally found only slight increases in solids, organic matter, ammonia, nitrogen, phosphorus, and water temperature, and slight decreases in pH and dissolved oxygen concentrations (Alabaster 1982; Heinonen 1984; Kendra 1991; Camargo 1992, 1994; Brown 1996; Selong and Helfrich 1998). Significant spikes of solids, ammonia, nitrogen, phosphorus, and oxygen demand have been documented during cleaning, feeding, and harvesting activities (Kendra 1991; Massik and Costello 1995; Boardman et al.1998; Selong and Helfrich 1998). Increases in chlorophyll *a*, periphyton, sewage fungus, and macrophytes have been observed below trout farm effluents (Alabaster 1982; Heinonen 1984; Kendra 1991; Loch et al. 1996; Selong and Helfrich 1998).

Boardman et al. (1998) conducted particle size analyses of the effluent from three trout facilities in Virginia. On a total number basis, the majority of particles in the effluent were found to be small (1.5-30 μm). On a mass basis, the larger particles (>105 μm) in the effluent were found to be more important. Fresh trout farm effluent was used in an eight-day batch study conducted in the laboratory to record particle degradation and settling. The results showed that particles in the 5-20 µm range in the water column increased from 57% to 85% in a period of six days. These findings are important for management purposes because smaller particles are more difficult to remove from the effluent.

3.2.1.3 Permit Requirements

DEQ personnel statistically analyzed Discharge Monitoring Report (DMR) data from Virginia trout facilities from 1990 to 1994. Although low levels of ammonia were detected in the untreated fish farm discharges, the DEQ concluded that none of the existing permitted facilities had concentrations that warranted inclusion of toxicity-based ammonia limits in the permits. The DMR data were also reviewed for BOD, dissolved oxygen, temperature, pH, and nutrients, and the effluents were found to be within the standards. Therefore, monitoring for these parameters is no longer required for trout farmers who hold general permits. For the trout facilities on the six impaired streams in this TMDL report, the monthly average total suspended solids (TSS) concentration in the effluent must not exceed 10 mg/L, and the maximum daily TSS concentration for individual effluent samples must not exceed 15 mg/L.

A DEQ review of the benthic surveys conducted for fish farms in 1995-1996 indicated impacts to benthics from solids. “It is concluded that solids are of concern with these effluents, and if controlled, water quality standards will be maintained” (DEQ 1998a).

3.2.1.4 Visual Surveys

Cockran Spring Branch, Wallace Mill Stream, and Lacey Spring Branch, have relatively long tracts with inadequate forest buffer along the streambanks, numerous erosion sites, and areas where livestock have access to the stream. Nonpoint source pollution from livestock is suspected to impact these streams.

Observations of trout in the impaired streams, particularly in Lacey Spring Branch and Pheasanty Run, prompted a fish survey to document the possible predation effects of trout on the benthic macroinvertebrate community.

Periphyton accumulations on the substrate were observed below all of the trout farm outfalls, except in Pheasanty Run. The biomass of periphyton appeared to be localized to the first several 100 feet below the trout farm outfall. Large masses of macrophytes were observed in the headwaters of Pheasanty Run, increased below the trout farm outfall, and remained significant throughout the entire impaired segment. These observations indicate that excess nutrients may be coming from the trout farms.

3.2.1.5 Stakeholder Input

One of the trout farmers indicated that the spring waters feeding his facility were high in nitrogen, which was confirmed by the TMDL physical/chemical monitoring. The farmer also commented that the spring was sometimes turbid after precipitation events, even when no rain had fallen at the farm but had fallen in other parts of the local area. This observation indicates the influence of surface water on this particular spring.

Another facility explained that under extremely dry conditions, when the spring water levels and the supplemented flow from a nearby creek are very low, the effluent is recirculated. Recirculating the effluent leaves the impaired stream segment dry.

3.3 CHARACTERIZE CANDIDATE STRESSORS

The advisory panel eliminated ammonia, dissolved oxygen, pH, and water temperature from consideration as critical stressors in these six impaired stream segments. Although toxic chemicals, excess nutrients, dissolved organic carbon, and fish predation could not be eliminated as likely stressors, they were judged not to be the most probable stressors. Instead, organic solids and hydraulic alterations were considered the most critical stressors.

3.3.1 Eliminated Stressors

3.3.1.1 Ammonia

Ammonia was present in some samples taken from the headwaters, most samples from the trout farm effluents, and within some samples from the impaired streams. Ammonia is known to be toxic to aquatic organisms. An EPA update of ambient water-quality criteria for ammonia ranked genus mean acute toxicity values and found rainbow trout (*Oncorhynchus mykiss*) and brown trout (*Salmo trutta*) to be more sensitive to ammonia than the studied macroinvertebrates (e.g., caddisfly, isopod, mayfly, amphipod, tubificid worms, and stonefly) (EPA 1999). Because trout are produced in the studied waters, it is unlikely that ammonia toxicity is a stressor to the benthic macroinvertebrates.

Ammonia toxicity is dependent on temperature and pH, with ammonia generally being more toxic at high pH levels. Wallace Mill Stream had the highest pH values. One sample taken near the end of the impairment had a pH of 8.3 and no detection of ammonia. All other samples taken in Wallace Mill Stream had pH values less than 8. All ammonia concentrations were less than 0.9 mg/L for Wallace Mill Stream. The lowest chronic ammonia criterion for freshwaters in Virginia with a pH of 8 is 1.55 mg/L (based on total ammonia) (9 VAC 25-260-140). Ammonia toxicity was therefore eliminated as a critical stressor in Wallace Mill Stream.

Montebello Spring Branch had the highest ammonia concentrations and the lowest pH values. All ammonia readings from Montebello Spring Branch were less than 2.0 mg/L (1.9 mg/L was the highest value), and the pH was always below 7.5. The lowest chronic ammonia criterion for freshwaters in Virginia with a pH of 7.5 is 2.5 mg/L (based on total ammonia) (9 VAC 25-260-140). Ammonia toxicity was therefore eliminated as a critical stressor in Montebello Spring Branch.

The other four studied streams had low total ammonia concentrations (0.00 - 0.53 mg/L), which were well below the chronic ammonia criteria for freshwaters in Virginia for the respective pH of the water. Ammonia toxicity was therefore eliminated as a critical stressor in Cockran Spring Branch, Lacey Spring Branch, Orndorff Spring Branch, and Pheasanty Run.

3.3.1.2 Dissolved Oxygen, pH, and Temperature

All measured dissolved oxygen, pH, and maximum temperatures within the impaired segments met the numerical criteria for their water classifications, thereby eliminating these parameters as probable stressors. The numerical criteria for dissolved oxygen, pH, and maximum temperature are given in Table 3.1 (9 VAC 25-260-50).

Table 3.1 Numerical criteria for dissolved oxygen, pH, and maximum temperature.

Water Class	**Dissolved Oxygen** (mg/L)		**pH**	**Maximum Temperature** (^{o}C)
	Minimum	Daily Average		
IV Mountainous	4.0	5.0	6.0-9.0	31
V Stockable	5.0	6.0	6.0-9.0	21

Cockran Spring Branch, Lacey Spring Branch, Orndorff Spring Branch, Wallace Mill Stream, and Montebello Spring Branch are Class IV streams (Mountainous Zone). Some of these stream segments (Cockran Spring Branch, Lacey Spring Branch, and Wallace Mill Stream) have special pH criteria of 6.5-9.5. All pH values within the impaired streams fell between 6.5-9.0, with the lowest pH being 6.5 in Montebello Spring Branch and the highest being 8.3 in Wallace Mill Stream. The maximum allowable temperature for the class is 31^{o}C, which is considerably higher than the highest temperature recorded in the summer conditions (24^{o}C). Minimum dissolved oxygen values of 4.0 mg/L and daily averages of 5.0 mg/L were also met. No water samples collected within the impaired segments had dissolved oxygen concentrations below 5 mg/L as determined using CHEMets® field kit, which uses the indigo carmine method. (A few August samples taken directly from the trout farm effluent at one farm were between 3-4 mg/L as determined by the indigo carmine method, but measurements taken by the Datasonde 4 at the benthic sampling location at the same time remained above 6.0 mg/L).

Table 3.2 shows minimum and daily average dissolved oxygen concentrations and maximum temperature values for impaired stream waters near the benthic sampling location as recorded every 15 minutes for a 24- to 48-hour period. Additional data are presented in Appendix B. These data meet the water quality criteria.

Table 3.2 Dissolved oxygen, and temperature values for four impaired streams. Measurements taken every 15 minutes for a 24-48 hour period.

	Dissolved Oxygen (mg/L)		**Maximum Temperature** (^oC)
	Minimum	Daily Average	
Class IV Criteria	**4.0**	**5.0**	**31.0**
Lacey Spring Branch	5.6	6.0	13.7
Montebello Spring Branch (1)	7.7	7.8	14.4
Montebello Spring Branch (2)	7.6	8.3	16.6
Orndorff Spring Branch	5.0	6.0	19.3
Wallace Mill Stream	6.3	6.8	19.9

The impaired segment of Pheasanty Run belongs to Class V (Stockable Trout Waters) and is a Virginia Department of Game and Inland Fisheries Class vi stream, meaning it is a cold water habitat not suitable for wild trout but adequate for year-round hold-over of stocked trout (9 VAC 25-260-370). Stockable Trout Waters must maintain dissolved oxygen concentrations above 5.0 mg/L, a pH between 6.0 and 9.0, and temperatures less than 21^oC (Table 3.1). The impaired segment of Pheasanty Run met these criteria. The dissolved oxygen levels were generally around 7 mg/L. One sample taken on a warm day in September (9/23/01) at 6:45 p.m. had an estimated dissolved oxygen concentration between 5 and 6 mg/L as determined by the indigo carmine method. The pH of the impaired segment of Pheasanty Run ranged from 7.4 to 8.6. The highest recorded temperature in the impaired segment was 18.3^oC.

3.3.2 Possible Stressors

3.3.2.1 Toxic Chemicals

Chemical additions to surface waters from industrial, urban, residential, and agricultural sources can be toxic to benthic macroinvertebrates by directly poisoning the organisms or by impairing their ability to reproduce (e.g., preventing eggs from hatching). The impaired stream segments in this study receive no runoff from industrial or urban sources. Residential sources of significant chemical contributions are unlikely because the few residential homes along the impaired streams would probably only offer occasional, low-concentration inputs of toxic chemicals.

Toxic chemicals used in agriculture production could potentially affect the benthic macroinvertebrate community. However, the advisory panel did not think the observed shift in the benthic macroinvertebrate community in these streams was due to agricultural chemicals. Because the impaired streams do not flow through cropland, they are unlikely to receive runoff carrying herbicides and insecticides very often. Herbicides may occasionally be applied to control thistles and other weeds in the pasturelands that feed the impaired streams but are unlikely to cause the long-term observed effects, particularly since some of the reference streams (Mill Creek and Ingleside Spring Branch) receive runoff from pastureland.

Trout production typically involves some chemical use. Surveys of the trout farmers indicated that some facilities do not use any chemicals in their production, while most reported occasional use of small amounts of chemicals. Salt and various fish therapeutics, including medicated feeds, were reported most often. Although chemical use was inventoried, no attempt was made to analyze the impaired waters for the chemicals used.

3.3.2.2 Fish Predation

The presence of escaped trout from the aquaculture facilities or stocked trout in the impaired stream may have increased predation of the benthic macroinvertebrates and thereby affected the macroinvertebrate community. Observations of fish in the streams prompted a study to determine if predation by trout is a possible stressor to the benthic macroinvertebrates. Fish surveys were consequently conducted in the two streams with the highest observed fish populations (Pheasanty Run and Lacey Spring Branch) and compared to their benthic macroinvertebrate reference site (Mount Solon Spring Branch).

Thirteen species of fish, including 133 introduced rainbow trout (*Oncorhynchus mykiss*) and 3 introduced brown trout (*Salmo trutta*) were represented in collections from Pheasanty Run (Overall fish abundance 9.9 fish per minute). Numerically dominant native species in Pheasanty Run were the white sucker (*Catostomus commersoni*) and mottled sculpin (*Cottus bairdi*). Selective predation by the large number of drift-feeding salmonids could potentially bias negatively the RBP assessments, particularly metrics involving Ephemeroptera and Trichoptera. However, a more detailed study of trout feeding ecology would be necessary to test the hypothesis. In contrast, only a single species of fish, introduced rainbow trout, was collected from Lacey Spring Branch. The relatively low abundance of trout (5.3 fish per minute) at this location makes it unlikely that fish predation could bias significantly the RBP assessments at the site (Appendix C).

3.3.2.3 Excess Nutrients

Excessive amounts of nutrients, nitrogen (N) and phosphorus (P), significantly increase the growth of algae, fungi, and rooted aquatic vegetation. Moderate increases in the biomass of primary producers can increase the food supply of benthic macroinvertebrates, and lead to an increase in the biomass of macroinvertebrates. Extreme increases in periphyton and macrophyte biomass can increase the demand for oxygen and thereby reduce the amount of oxygen available to the macroinvertebrates and negatively impact them.

Excess nutrients from both point and nonpoint sources were considered as likely stressors. Observations of increased biomass of periphyton and macrophytes below the trout farm outfalls in comparison to the rest of the stream and in relation to the reference streams indicate that excess nutrients may be coming from the trout facilities. Livestock with access to the impaired streams and runoff, which may carry nutrients from fertilizers and manure, are potential nonpoint source contributors.

Laboratory data indicated that a large portion of the total Kjeldahl nitrogen (TKN, the organic forms of nitrogen and ammonia) in the trout effluent and the impaired waters were sediment bound (Appendix D). The total phosphorus (TP, organic and inorganic forms) was almost 100 percent sediment bound. The advisory panel of experts concluded that management activities to control the solids would also control the excess nutrients reaching the impaired streams. Thus, although excess nutrients are believed to be probable stressors, the TMDL would focus on reducing solids.

3.3.2.4 Dissolved Organic Carbon (DOC)

Organic enrichment, which leads to high dissolved organic carbon levels and associated high biochemical oxygen demand, results in low oxygen concentrations in the water and stream substrate. The consequences of low oxygen concentrations include: a decrease in the number of oxygen-sensitive organisms, an increase in low-oxygen tolerant organisms, and therefore changes in the macroinvertebrate community composition. Deposited organic sludge can also form a blanket over the substrate and result in the loss of interstitial organisms.

The results of the benthic macroinvertebrate surveys indicated that excess input of organic material might be causing a shift in the macroinvertebrate community. The grayish tint of the water sometimes observed suggested organic input as well. It is difficult, however, to quantify and trace carbon through the system because all organic material contains carbon, and carbon also has inorganic and gaseous states.

Water samples from the impaired streams, trout farm effluents, and reference streams were analyzed for dissolved organic carbon (DOC), which refers to the carbon within the water column. DOC is available to bacteria and other microorganisms as a source of energy. High concentrations of dissolved organic carbon (DOC) in freshwater may indicate pollution by anthropogenic sources. DOC can come into the system from other watersheds through groundwater. Nonpoint sources of DOC can originate from leaching of the forest canopy, leaf residue, and incomplete decomposition of organic matter. Potential point sources of DOC for the watersheds in this study include fish feed and animal waste in the effluent from the trout farms.

The highest DOC concentration, 5.0 mg/L, was obtained in July 2001 from a stream fed by a wet weather spring that discharges into Orndorff Spring Branch. This small stream is located in a forested area and does not receive any point discharge. During sampling in the stream in January 2002, a deer skeleton and partial skull of a smaller mammal were found in the stream above the water sampling site, offering a possible explanation for the earlier DOC concentration.

Waters that receive surface runoff appeared to have higher DOC concentrations. The average DOC concentration was 2.2 mg/L in the upper reaches of Pheasanty Run (above the trout farm effluent) compared to 1.2 mg/L for the springs that are the headwaters of the trout farm, 1.3 mg/L for the trout farm effluent, 1.2 mg/L for samples from the benthic sampling site, and 1.3 mg/L for the end of the impairment. Also, Mill Creek had higher DOC levels after a rainstorm event (4.9 mg/L) than during a time in which no rain had fallen for days (1.1 mg/L).

General trends were observed in some of the DOC data. For example in Wallace Mill Stream, the DOC concentrations of the headwaters ranged from 0.3 to 0.8 mg/L over a three-day period (average 0.5 mg/L, n = 4). The trout farm outfall DOC averages were always higher than the headwaters average. Outfall averages for three feedings had DOC values of 1.1 mg/L (n = 6), 1.4 mg/L (n = 6), and 1.8 mg/L (n = 7), and a harvesting value of 1.0 mg/L (n = 1). Additionally, sample DOC concentrations taken at the farm outfall were always higher than those taken from the end of the first series of raceways.

The waters of Montebello Spring Branch consistently had the highest DOC values. This is also the stream where tubifex worms–indicators of organic pollution–were observed. Feeding, harvesting, and cleaning activities appeared to increase the DOC concentrations of the trout farm effluent, but definite conclusions were not possible because of the variability of the DOC concentrations in the headwaters:

2.2 mg/L (range 2.1-2.3 mg/L; n = 3; July 18-19, 2001);
1.2 mg/L (range 0.9-1.6 mg/L; n = 4; August 14-16, 2001);
0.9 mg/L (n = 1; January 29, 2002).

The headwaters of Orndorff Spring Branch showed considerable variations over a short time. Five days of sampling yielded headwater DOC concentrations of 1.6, 1.8, 3.1, 0.6, 0.4, 0.7, and 0.7 mg/L. The highest concentration (3.1 mg/L) was obtained a day before a rain event; and the samples taken the days after the rain event were lower than those taken before the rain.

Four samples taken from each reference benthic sampling site had the following DOC concentrations:

Ingleside Spring Branch ranged from 0.8 to 2.9 mg/L;
Mill Creek ranged from 1.1 to 4.9 mg/L; and
Mount Solon ranged from 0.7 to 1.4 mg/L.

Additionally, the Lacey Spring Branch benthic sampling site had lower DOC concentrations (0.6 mg/L) than did the headwaters (1.2 mg/L).

Organic enrichment remains a potential and likely critical stressor, but DOC data did not distinguish how the carbon was flowing through the system. Because the solids taken from the settling basins at the trout farms were highly organic in nature, up to 83 percent volatile solids, at least some of the carbon flow should be reflected in the TSS values. The advisory panel of experts concluded that management activities to control the solids would control the excess DOC reaching the impaired streams.

It is suggested that other forms of carbon might provide useful information in follow-up monitoring. For instance, analyses of particulate organic carbon (POC) might provide more information than did DOC. Kondratieff and Simmons (1982) studied the effects of sewage input on macroinvertebrates inhabiting a stream, by examining DOC concentrations and POC concentrations. They found POC concentrations to be to be significantly higher immediately below the outfall and incrementally decline downstream. The DOC concentrations were not significantly different between stations. The DOC data were far more variable than the POC data, and the DOC concentrations were higher than the POC concentrations. Kondratieff and Simmons concluded that all the added POC was being utilized by the organisms in the stream or were being converted to DOC or some inorganic form.

3.3.3 Critical Stressors

3.3.3.1 Organic Solids

Solids in general have multiple effects on the benthic macroinvertebrate community. Solids can interfere with the respiration of benthic macroinvertebrates. Deposited solids that fill the interstitial spaces of the substrate reduce the available habitat for some macroinvertebrate species. Solids in water reduce the photosynthesis capabilities of aquatic plants, which are the food source for some benthic macroinvertebrates, and may clog the feeding nets of other benthic macroinvertebrates. Solids reduce the visibility in the water and can thus lower the success rate of predatory macroinvertebrates in capturing prey.

A discussion by the advisory panel of experts concluded that not only is the load of the solids important in this TMDL study, but the type of solids is also important. Wallace Mill Stream illustrates this point. This stream has two benthic monitoring sites. The upstream site is severely impaired in terms of the benthic macroinvertebrate community, and the downstream site is moderately impaired. The upstream site has a smaller load of total solids but a higher organic solids load compared to the downstream site because the point source, which is located immediately upstream of the severely impaired benthic site, has a much higher organic content than the solids from the nonpoint sources. The lower organic solids load therefore offers a reason for the observed improvement in the benthic macroinvertebrate community at the downstream site on Wallace Mill Stream despite this site having a higher total solids load.

The organic component of the solids was identified as the critical stressor in all six impaired streams owing to several factors. The dominant organisms in the benthic samples for the six impaired streams (e.g., oligochaetes) are tolerant of high organic loads. Taxa intolerant of high loads of organic solids, such as Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (stoneflies), were rare or absent in the impaired streams. Published studies have found organic solids to negatively impact the benthic community and describe oligochaetes and chironomids (dominant taxa observed in the DEQ and TMDL benthic samples from the impaired streams) as typical for organically enriched waters (Hellawell 1986; Kondratieff and Simmons 1982; Carmago 1992, 1994; Brown 1996). Solids, which were found to be on average 60 percent organic, were observed in settling areas within the trout facilities in depths up to 14 inches. The high organic content of aquaculture sludge is consistent with other studies (Westerman et al. 1993, Boardman et al. 1998). In summary, organic solids were identified as the critical stressor based on 1) the benthic monitoring results in the impaired segments, 2) a literature review of the effects of organic solids on benthic macroinvertebrate communities, 3) visual observations of accumulated solids in the trout farm raceways and the listed stream segments, and 4) data collected for the TMDL report.

3.3.3.2 Hydraulic Load

Hydraulic alterations, either high flows or low flows, can negatively impact the benthic community and be a critical stressor. High flows can be caused by increased surface-runoff from adjacent lands (including flooding). High flows can scour the substrate, move rocks and other valuable habitat areas downstream, and often carry higher loads of sediment and other pollutants. Flooding is considered a natural hydraulic alteration from which the macroinvertebrates have evolved to survive; given sufficient time, the benthic community will rebound following a flood. Flooding, therefore, was not incorporated into the TMDL calculations. Other high flow events, such as following a thunderstorm, are included in the nonpoint source estimates.

Sustained low flows reduce the available habitat for aquatic organisms. Low flow conditions are associated with higher water temperatures and consequently reduced oxygen holding capacity of the water. The headwater springs for five of the streams sustain enough flow to support aquatic life year-round.

Low flows resulting in long-term dry conditions or inadequate water in Montebello Spring Branch is considered a critical benthic stressor. The spring flows for Montebello Springs Branch are extremely variable, estimated from 20 gallons per minute (GPM) to 400 GPM in a given year. The trout facility is unable to rely on springs as its sole source of water, and generally pumps water from nearby Mill Creek to compensate for periods of low flow. In extreme situations, when Mill Creek also runs low, the effluent from the trout facility is recirculated, and no water flows through Montebello Spring Branch.

3.4 STRESSOR LOADS AND SELECTED ENDPOINTS

3.4.1 Organic Solids

Organic solids were identified as the critical stressor in all six impaired streams (See Section 3.3). The sources of organic solids were identified, and the total load was apportioned to natural background, point sources, and nonpoint sources. The load of organic solids attributed to the natural background and point sources were determined from measurements of total suspended solids and its estimated organic content fraction. Sediment load, as calculated from the Revised Universal Soil Loss Equation (RUSLE), and estimated organic content were used to describe the nonpoint source organic solids contributions.

Solids originating from aquaculture facilities are primarily uneaten fish feed and fish wastes so are therefore highly organic in nature. In the laboratory, percent organic matter can be obtained by measuring the percent volatile solids (organic material) in the total solids. Westerman et al. (1993) found solids in trout raceways and sediment traps to be about 77 percent organic and solids from settling basins to be 61 percent organic. Boardman et al. (1998) found the organic content of sludge from a trout farm in Virginia to range from 44 to 63 percent, with an average of 56 percent. Volatile solids were not measured in the effluent from the trout farms under study, but solids collected from the settling basins of three of the farms had an average organic content of 60 percent. An organic content of 60 percent was therefore used in the TMDL calculations, although this value is considered to be lower than expected for solids in the effluent.

The soils for the areas under study are naturally 2.5 percent organic (from soil surveys). An organic content higher than this was used in the TMDL calculations to account for contributions from runoff containing organic matter picked up on the surface (e.g., manure). Estimates show that organic matter content in sediment from agricultural fields and forests generally ranges from 1-10 percent (Foth 1990). The organic content of soils consists of humus and labile fractions. The labile organic fraction originates from plant residues, animal waste, and other easily degradable organic matter. In general, the labile organic matter constitutes a small fraction (only 10 to 20 percent) of the total soil organic matter (Foth 1990). For the TMDL calculations, an estimate that is believed to overestimate the true value was used. An estimate of five percent total organic content was used to describe the solids originating from nonpoint sources. The five percent organic content was also used in the load calculations for the spring waters because organic solids from the springs in this study most likely originate from nonpoint source runoff.

Because Virginia does not have a criterion for organic solids, a reference watershed approach was used. The load of organic solids in the reference stream or target condition was estimated and used to set the endpoint. The endpoint was calculated by first estimating the total solid load to the stream and then determining the organic solid load to the stream from the percent organic matter in the total solid load.

Ingleside Spring Branch is the reference stream for the organic solids target for all six impaired streams (See Section 3.4.3). Only nonpoint sources of pollution were identified in Ingleside Spring Branch. Therefore, total solids were estimated using the RUSLE. The reference watershed approach was modified to consider only the sediment load from the affected stream riparian zone within the watershed. The riparian zone was defined as a 300-foot land strip on each side of the stream segment. Literature indicates that steam water quality is more critically affected by the conditions of the riparian zone relative to total watershed area because canopy cover and vegetation in the riparian zone can affect water temperature, nutrient supply, and sediment input into the stream (Davies and Nelson 1994, Tufford et al. 1998).

Owing to differences in stream length between the impaired segments and the reference stream, the target sediment load estimate for each impaired segment was adjusted to compensate for differences between riparian areas of the impaired segment and its reference. This adjustment was necessary because riparian size influences sediment delivery to the stream. For example, the riparian area for the impaired segment of Wallace Mill Stream is 65.23 acres, and the riparian area for the reference stream (Ingleside Spring Branch) is 12.06 acres. The estimated sediment load (target) for the Ingleside Spring Branch reference stream is 6.38 tons per year. This value was multiplied by 65.23/12.06 to obtain the area adjusted sediment target of 34.51 tons per year for Wallace Mill Stream.

The estimated target sediment load (tons per year) was converted to organic solids load (pounds per year) by multiplying the sediment load by the percent organic matter content of soil. An estimate of five percent organic matter content was used to account for the organic matter content originating from nonpoint sources. As an example, for Wallace Mill Stream the reference sediment load (target) was adjusted by multiplying 34.51 tons per year by 0.05 to obtain the adjusted target of 1.73 tons per year (3,451 pounds per year) organic solids.

3.4.2 Hydraulic Load

The advisory panel concluded that that under natural drought conditions, Montebello Springs cannot produce enough water to sustain aquatic life in Montebello Spring Branch so did not recommend that a minimal hydraulic load be maintained in Montebello Spring Branch. DEQ and EPA, however, will need to review the situation. A variance may be granted, or the facility may need to discharge to Montebello Spring Branch at least the amount of spring flow at all times. A more detailed discussion is provided in Section 9.5.

3.4.3 Reference Target Selection

Three reference sites were used to interpret the results of the benthic macroinvertebrate surveys of the six impaired streams (one reference stream per impaired stream). Ingleside Spring Branch is the benthic reference for limestone, spring-fed streams with small flows in the Central Appalachian Ridge and Valley ecoregion. Mount Solon Spring Branch is the benthic reference stream for limestone, spring-fed streams with large flows in the Central Appalachian Ridge and Valley ecoregion. Mill Creek is the benthic reference for Montebello Spring Branch, a non-limestone, spring-fed stream in the Blue Ridge Mountains ecoregion. Ideally, the benthic reference site would be used to set the organic solids target because the characteristics, particularly the chemical/physical characteristics, should be most similar. However, this is not always the case (See Section 2.2).

Ingleside Spring Branch was used as the benthic reference stream for Orndorff Spring Branch and Wallace Mill Stream in the initial DEQ impairment listing and is used as the organic solids load target condition for these two streams in the TMDL calculations. Mount Solon Spring Branch was initially used as the benthic reference by DEQ to determine the impairment listing for Cockran Spring Branch, but Ingleside Spring Branch was used as the benthic reference for the TMDL study owing to substantially lower flows in Cockran Spring Branch in recent years and more similar water chemistry. For these same reasons, Ingleside Spring Branch was used as the organic solids load reference for Cockran Spring Branch in the TMDL calculations.

For the benthic impairment designation, Mount Solon Spring Branch was the reference stream for Lacey Spring Branch and Pheasanty Run. However, Mount Solon Spring Branch was not used as the organic solids reference for the TMDL calculations. Mount Solon Spring Branch receives effluent from a small sewage treatment plant (STP) for an apartment building. Water samples of the effluent were not collected, and the STP is not required in its permit to measure total suspended solids (TSS). Therefore, the point source organic solids contributions of Mount Solon Spring Branch could not be calculated.

Although Mount Solon Spring Branch was the reference stream for Lacey Spring Branch, it was not used as the organic solids reference in the TMDL calculations. Using the nonpoint source contributions to Mount Solon Spring Branch to set the target does not offer an attainable condition for Lacey Spring Branch. Using Mount Solon Spring Branch as the reference for Lacey Spring Branch would result in a target organic solids load of 366 pounds per year. The headwaters (spring) of Lacey Spring Branch yield 1,127 pounds per year of organic solids. Even after eliminating all point sources and nonpoint sources along Lacey Spring Branch, the load from the spring would need to be reduced by two-thirds (67 percent) to meet the Mount Solon based target. It was concluded, therefore, that Mount Solon Spring Branch is not a suitable organic solids target for Lacey Spring Branch. In its place, Ingleside Spring Branch was used as the target. The water chemistry of Lacey Spring Branch is more similar to Ingleside Spring

Branch than it is to Mount Solon Spring Branch and Mill Creek. However, Lacey Spring Branch and Ingleside Spring Branch are also not truly compatible in water chemistry so the implementation plans need to account for this difference.

Mount Solon Spring Branch was used as the benthic reference stream for Pheasanty Run. However, Mount Solon Spring Branch was not used as the organic solids reference for the TMDL calculations. Of the three benthic reference streams used in this study, Mount Solon Spring Branch is the most suitable as a reference stream for Pheasanty Run in terms of TDS, alkalinity, hardness, flow, and watershed size, despite significant differences between the flows and watershed sizes. Using the nonpoint source loads of Mount Solon Spring Branch to set the organic solids load target for this impaired stream would provide a stringent goal of 606 pounds per year. Given the uncertainties and knowledge that point source pollution was not accounted for in Mount Solon Spring Branch, the argument to use a less stringent target is valid.

In comparison to Mount Solon Spring Branch, Ingleside Spring Branch had more macroinvertebrate taxa, a higher density of organisms, and a lower mean HBI value, indicating that Ingleside Spring Branch is a slightly higher quality stream in terms of the benthic macroinvertebrate community (Appendix A). In comparison to Mill Creek, Ingleside Spring Branch would be more appropriate as an organic solids load reference for Pheasanty Run in terms of spring water chemistry.

Mill Creek is the benthic reference stream for Montebello Spring Branch but was not used as the organic solids reference in the TMDL calculations. In terms of TDS, alkalinity, and hardness, Mill Creek and Montebello Spring Branch are similar, although Mill Creek receives much more overland flow than does Montebello Spring Branch. A target organic solids load of 38 pounds per year would be obtained using Mill Creek as the organic solids load reference for Montebello Spring Branch; the organic solids load from runoff in the deciduous forest portion (and disregarding runoff contributions from the gravel drive and the point source) of the Montebello riparian buffer area yields 43 pounds per year of organic solids. Mill Creek therefore is not a suitable reference for setting the organic solids load target. Consequently, Ingleside Spring Branch, the reference stream with a more similar flow to Montebello Spring Branch, was used.

In using a reference watershed approach to allocate nonpoint source loads in TMDL calculations, the physical similarity between the reference watershed and the impaired watershed is critical. Important physical features include watershed size, soil type, land use or cover condition, and topography. Topography (represented as the LS factor in the RUSLE) and land use cover condition (represented as the C factor in the RUSLE) are critical for nonpoint source load calculations. The slope characteristics of the riparian area of Ingleside Spring Branch (LS average < 2) are similar to those in the riparian area of Lacey Spring Branch and Pheasanty Run (LS average < 2), indicating relatively shallow slopes. The land cover condition of the Ingleside Spring Branch riparian area is mostly pasture/grassy field and is similar to the land cover conditions of the riparian area of Lacey Spring Branch (which has a large portion as pasture/grassy field) and Pheasanty Run (which is mostly a grassy field). The Montebello Spring Branch riparian area topography and land cover characteristics are different from Ingleside Spring Branch. However, nonpoint sources do not significantly contribute to the percent total load of organic solids in Montebello Spring Branch (See Section 9.6).

Owing to the uncertainty in other aspects of using the reference watershed approach (see Section 13.1), the project advisory panel decided that using the Ingleside Spring Branch riparian area as a target for the organic solid load reductions for Lacey Spring Branch, Pheasanty Run, and Montebello Spring Branch would not add significant uncertainty to the process. Therefore, Ingleside Spring Branch was used as an organic solids reference for all six impaired segments. A viable benthic community is attained at Ingleside Spring Branch, and in comparison to the impaired stream segments, Ingleside Spring Branch has a lower organic solids load when corrected for area. A viable benthic community should therefore be possible for the impaired sites if their current organic load is reduced below the level in Ingleside Spring Branch.

4 COCKRAN SPRING BRANCH TMDL

4.1 INTRODUCTION

In 1996, an unnamed tributary called Cockran Spring Branch in this report and known locally as Cale Spring Stream was declared impaired for failing to support aquatic life (DEQ 1998b). The impaired segment is 0.8 miles in length, begins at the outfall of a trout facility, and continues to the confluence with Middle River. The effluent from the trout facility was suspected as the cause of the impairment, but the exact pollutant or pollution causing the impairment was not identified. The stream received a priority of "medium" for not/partially supporting the aquatic life use.

4.1.1 Watershed Background

Cockran Spring Branch is a first-order stream with a perennial spring as the headwaters. Cockran Spring Branch discharges into Middle River, which drains to the Shenandoah River Basin and eventually flows into the Chesapeake Bay. The Cockran Spring Branch watershed is part of the Shenandoah River hydrologic unit number 0207005 with watershed identification code VAV-B10R. The watershed drainage area lies in the Central Appalachian Ridge and Valley ecoregion in Augusta County, Virginia.

The benthic macroinvertebrate surveys of the impaired segment were compared to surveys taken from a reference stream to obtain the impaired status. The reference stream for the initial listing is a part of Mount Solon Spring Branch. This reference stream is located in Augusta County, Virginia. Mount Solon Spring Branch is used as the benthic reference for limestone, spring-fed streams in the Central Applachian Ridge and Valley ecoregion with large flows.

Ingleside Spring Branch is used as the benthic reference for limestone, spring-fed streams in the Central Applachian Ridge and Valley ecoregion with small flows. Because of substantially lower spring flows in recent years and higher similarities in the water chemistry in terms of TDS, alkalinity, and hardness (See Section 2.2), Ingleside Spring Branch was used as the reference stream in the TMDL study. Water from Ingleside Spring feeds two channels: one side flows through a trout rearing facility and the other flows through an open field. The reference stream is located in the section that flows through the open field. It is located in Rockbridge County, Virginia.

Watershed delineation for both the impaired stream segment and the reference streams followed natural topographic drainage divides (Appendix E). The watershed area for Cockran Spring Branch is about 940 acres, and the watershed area for the TMDL reference stream, Ingleside Spring Branch, is approximately 50 acres. The watershed area for the reference stream used for the initial listing, Mount Solon Spring Branch, is approximately 220 acres.

The land use for the Cockran Spring Branch watershed is pastureland and hayfields (79%) and deciduous forest (21%). The watershed contains one gravel/paved road and three gravel driveways, which account for less than 1% of the watershed area. The land use for the watershed of Ingleside Spring Branch is pastureland (99%) and a road, Route 612 (1%). The land use for the watershed of Mount Solon Spring Branch is residential (52%), pastureland (46%), and deciduous forests (2%). Water runoff from Routes 731 and 747, as they transect the watershed, drains to Mount Solon Spring Branch.

4.2 BENTHIC MONITORING

4.2.1 DEQ Benthic Monitoring

DEQ's biological monitoring on June 1, 1995 (using Rapid Bioassessment Protocol (RBP) II) indicated severe benthic impairment on Cockran Spring Branch compared to the reference, Mount Solon Spring Branch. Only four macroinvertebrate taxa of relatively pollution tolerant organisms were observed in Cockran Spring Branch. Approximately 98 percent of the organisms came from a single family, the Asellidae (sow bugs). The Asellidae, which are scavengers, were found in extremely high density, and a high density of scavengers is common in enriched waters (Bolgiano 1995a). Additional macroinvertebrate sampling in August 2000, revealed similar results (Van Wart 2000a).

On June 1, 1995, DEQ also monitored two stations on Middle River. One station was situated upstream of the confluence with Cockran Spring Branch, and one was 0.42 miles downstream of the confluence. The Middle River sites were determined to be moderately impaired compared to their reference site, Big Run in Page County. The downstream Middle River site was described as "clearly inferior to a decidedly 'imperfect' Middle River upstream of the confluence. This is a condition counter to what would be expected . . . were an undeveloped spring to enter a moderately impaired stream" (Bolgiano 1995a).

4.2.2 TMDL Benthic Monitoring

As a part of the TMDL study, it was recommended that a more in-depth benthic study be conducted to provide additional data for further evaluation of the impaired status of the streams (Appendix A). Because of the change in flow in recent years for Cockran Spring and owing to more similar water chemistry results, Ingleside Spring Branch was used as the reference stream for Cockran Spring Branch instead of Mount Solon Spring Branch.

Ingleside Spring Branch (TMDL Study Reference Site):

The benthic community at Ingleside Spring Branch was composed of a variety of species, 23 taxa occurring in the five replicate samples combined and five of those being Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (stoneflies) (EPT) taxa. Scrapers dominated the community because of the abundance of the snail *Somatogyrus*, by far the most abundant taxon at the site. The mean HBI value of 6.2 reflected a community composed of primarily "moderately tolerant" taxa. Few taxa with HBI values indicative of "highly tolerant" species were common at the site, whereas a number of taxa that have low HBI values, indicating "intolerant" species, were common.

Mount Solon Spring (DEQ Reference Stream Used for Listing Cockran Spring Branch):

The benthic community at Mount Solon Spring was composed of slightly fewer taxa than were found at Ingleside Spring Branch, 19 taxa occurring in the samples. Only three of the taxa were EPT taxa. Isopods were the most common taxon, but overall no single or even a few taxa dominated the community in terms of abundance. Four taxa of snails were found; the two taxa of pleurocerid snails were fairly common whereas the other two taxa occurred only in one sample each. The abundance of isopods made the relative abundance of shredders the highest of the functional feeding groups. The mean HBI value of 7.3 reflected a community composed of "moderately tolerant" to "tolerant" taxa.

Cockran Spring Branch:

The benthic community at Cockran Spring Branch was significantly different from its reference site (Ingleside) in all metrics except density of organisms. Only five taxa occurred in the samples and all but one of them were highly tolerant taxa. No EPT taxa occurred in the samples from this site. The mean HBI value of 9.2 was the highest value for all of the sites. The community was dominated by isopods and oligochaetes, similar to findings from previous DEQ benthic surveys.

In summary, Cockran Spring Branch was clearly impaired. Only five taxa occurred in the samples from this site, and the three taxa that were numerically dominant are all very tolerant taxa. Far greater species richness, EPT richness and different abundance patterns of functional feeding groups would be expected if the stream were not impaired.

4.3 VISUAL SURVEY

The objective of the visual survey was to document environmental conditions with potential to affect the benthic community. The visual survey involved observing and cataloging water and land conditions, land and water uses, and the changes that take place along defined stream segments (Appendix F).

Ingleside Spring Branch (TMDL Study Reference Stream):

The visual survey of Ingleside Spring Branch encompassed approximately 500 feet of the stream. The survey began just below the spring and continued downstream (on the side not used for the trout farm) to the confluence with North Buffalo Creek. Adequate riparian vegetation (e.g., tree canopy) was lacking for the entire stream length on both banks. The land adjacent to the stream consisted of the trout farm on the left stream bank (not the trout farm under study) and an open field on the right bank. Livestock does not have access to the stream. One channel alteration was documented: three metal pipes to allow flow under a gravel drive that crosses the stream.

Mount Solon Spring (DEQ Reference Stream Used for Listing Cockran Spring Branch):

Mount Solon Spring is located in the town of Mount Solon. A concrete wall impounds the spring. The visual survey included the area from where the water exited the impoundment to a length of less than 200 feet. The water going over the spillway enters a pipe and flows underground for approximately 75-100 feet. The spring water enters the stream from a concrete pipe. The effluent from a small sewage treatment facility for a building with three apartments enters the stream on the left through a four-inch plastic pipe. The left stream bank is mostly lawn, and the right side is a wetland area with some trees. Three trash piles were documented: residential trash in and by the water as it exits the underground pipe, a few tires on the left side near the sewage treatment discharge, and about 120 square feet of ground covered by large sheets of scrap metal by the stream and close to the road. A drainage ditch along Route 731 (Natural Chimney's Road) feeds to the stream. The lower boundary of the visual survey occurred where the stream flows through three three-foot metal corrugated pipes to pass under Route 731.

Cockran Spring Branch:

The headwaters of Cockran Spring Branch are a perennial spring at the foot of a partially tree-covered hill. The stream flows through a series of raceways for rearing trout. A second series of raceways are adjacent to the first series but are no longer used for raising trout. Solids from the raceways are swept to a side stream that drains a pasture field. Cattle have access to the side stream. The side stream and trout farm effluent merge and flow through pasture fields to Middle River.

The visual survey included the impaired segment of Cockran Springs Branch from the raceway discharge downstream to the spring's confluence with Middle River. In the upper reaches of the stream, one point discharge site was observed: the trout farm effluent. Periphyton was observed on the substrate for the first several 100 yards of the impaired segment.

A trash site was observed off the right bank. The trash site consisted of a pile of construction and woody debris including large scraps of metal. An earthen channel that probably serves as a drainage ditch for the adjacent field was located on the right bank approximately 550 feet downstream of the trout farm discharge.

Eleven streambank erosion sites totaling 685 feet were documented along the impaired segment during the visual survey. They ranged from 30 feet to 100 feet in length and were mostly two to three feet in height. The erosion sites coincided with livestock access to the stream, with livestock having access to almost the entire impaired segment. The erosion was causing the stream bank to widen. Five erosion sites were located by bends at steep slopes. Noticeable increases of sediment on the streambed were observed below some of the erosion sites. Only one erosion site was somewhat stabilized by a buffer of shrubs and trees.

Riparian buffer zones of tall vegetation were inadequate to varying degrees for the entire stream length. In most instances, both stream banks were surrounded by open pastureland with no trees or shrubs. In only one section were shrubs present along the right bank.

4.4 PHYSICAL/CHEMICAL MONITORING

4.4.1 DEQ and Other Physical/Chemical Monitoring

A review of the quarterly discharge monitoring reports (DMR) from March 1999 to December 1999 and from April 2001 to December 2001 indicates compliance with the permit. Facility personnel also report compliance with the permit for the past five to ten years. Based on the discharge monitoring reports obtained from Virginia DEQ, an estimated 5.2 tons per year of TSS comes from the facility.

Boardman et al. (1998) obtained inlet, within farm, and outlet water quality data for three trout farms in Virginia from September 1997 to April 1998 on a bi-monthly basis. Their TSS findings are shown in Table 4.1. Using the average TSS concentrations from the Boardman et al. (1998) farm effluents with the lowest and highest TSS concentrations (Farm A, 3.0 mg/L; Farm C, 5.8 mg/L) and a spring flow of 1.34 cfs (comparable to the spring flow in this study), a TSS load of 4.0 tons per year to 7.7 tons per year could be expected.

Table 4.1 Total suspended solids concentrations for trout farms A, B, and C. "Within Farm" refers to data obtained from the end of all active raceways in each farm.

	Farm A			Farm B			Farm C		
(mg/L)	Inlet	Within Farm	Outlet	Inlet	Within Farm	Outlet	Inlet	Within Farm	Outlet
TSS range	0-1.1	0-30.4	0.8-6.0	0-1.8	0-43.7	1.5-7.5	0-1.5	0-28	4.1-62
TSS average	0.2	3.9	3.2	0.5	5.3	3.9	0.3	7.1	6.1*

*Two outliers removed for calculation of the average

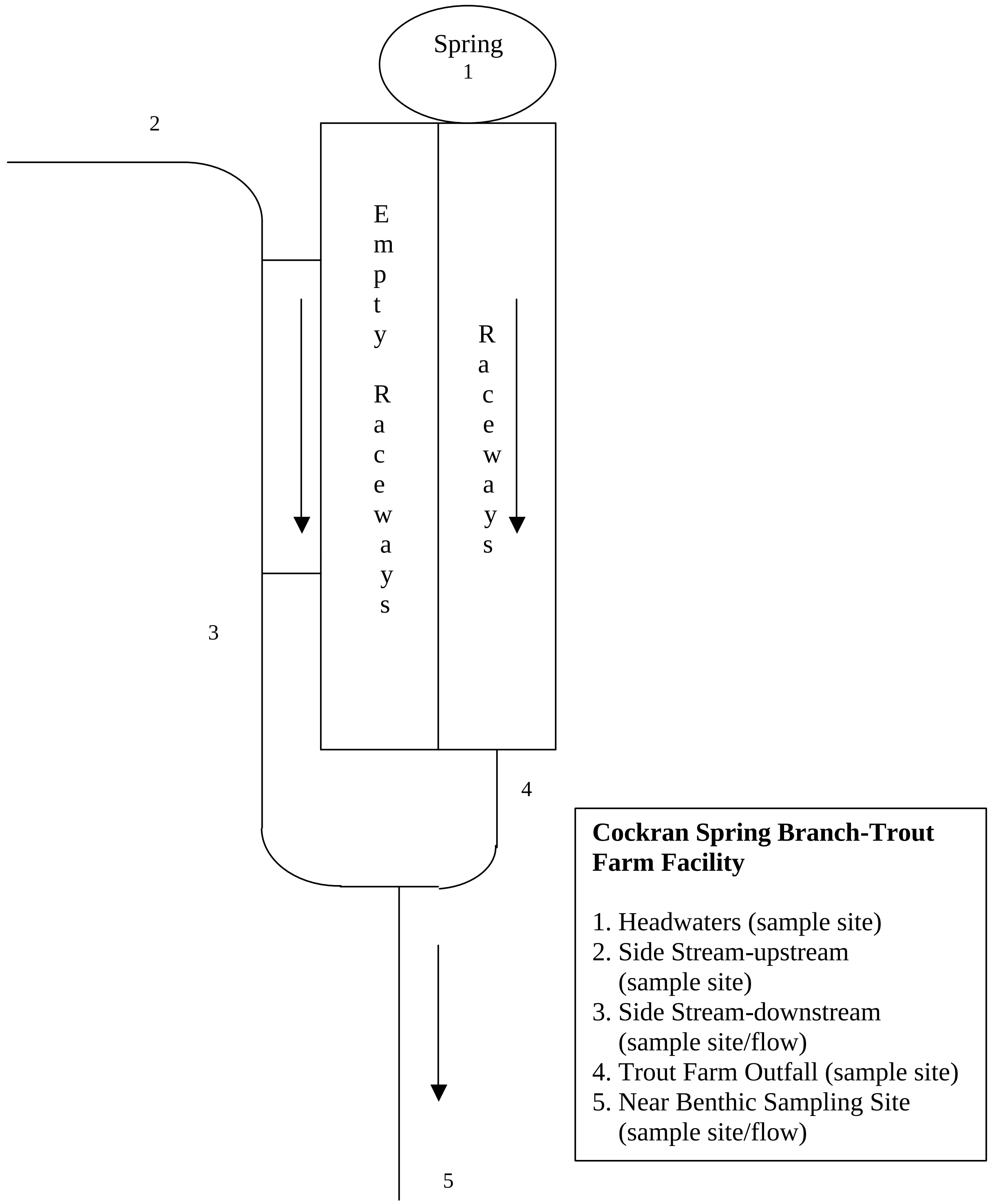
4.4.2 TMDL Physical/Chemical Monitoring

Sampling at the trout facility for the TMDL study occurred between August 3, 2001 and January 29, 2002 (Appendix G). Samples were collected from the spring, side stream, trout facility outfall, near the benthic sampling location, and near the end of the impairment (Figure 4.1).

The TMDL water quality data showed trends in the solids (Appendix H). Sampling was conducted in August when only a few fish were at the farm (repairs were being made in the raceways), and the obtained TSS concentrations were 0.00 mg/L (TSS detection limit = 0.001 mg/L). The stream running along side the trout facility receives solids from the trout raceways and is accessible by cattle. When cattle were in the stream, the TSS concentrations were 44.00 and 74.25 mg/L. When cattle were not in the stream, the TSS concentrations were 4.00 and 4.89 mg/L.

The total trout farm loading was estimated by adding the load from the trout farm effluent and the load from the side stream when no cattle were present. The addition of the load from the side stream may over-estimate the load since nonpoint and point sources influence this stream. Because the large majority of water in the side stream comes from the trout farm raceways, it is necessary to consider this stream as being under the influence of the trout farm. Sampling from the farm outfall and side stream during September 2001 and January 2002 yielded results of 4.9 tons per year in TSS.

Figure 4.1 Diagram of sample collection sites and stream flow measurement sites for the trout facility on Cockran Spring Branch. Not drawn to scale.



4.5 POLLUTION SOURCES

Table 4.2 presents the existing average annual organic solids load for Cockran Spring Branch.

Table 4.2 Existing organic solids loading in Cockran Spring Branch

Source Catgory	Organic Load (pounds per year)	Percent of Total Load
Headwaters (Spring)	9	0.1 %
Point Source (Trout Farm)	5,848	90.6 %
Nonpoint Source (Pasture)	600	9.3 %
Total Existing Load	6,457	100 %

4.5.1 Natural Background Loads

Samples taken from the headwaters of Cockran Spring on four occasions had only one TSS concentration above the detection limit (0.001 mg/L, Appendix H). The detected sample had a concentration of 0.20 mg/L. The estimated spring flow of 1.83 cfs gave an estimated TSS load from the spring of 0.1 tons per year. Using an estimated five percent organic content gave an organic solids load of 9 pounds per year from the spring.

4.5.2 Point Source Loads

A single point source was documented in the Cockran Spring Branch watershed. This source is an aquaculture facility that raises trout for stocking and processing, but no processing takes place at the facility. The trout farm holds a general permit (Virginia Pollutant Discharge Elimination System Permit VAG131001) that requires quarterly monitoring of discharge flow, total suspended solids, and settleable solids. According to the general permit, the facility should monitor the effluent once every three months for the following parameters:

1) Estimate flow (million gallons per day, MGD) at the time of the sampling. There is no effluent limit for flow.
2) Report monthly average and daily maximum total suspended solids (TSS) from a composite sample, i.e., hourly grab samples, not to exceed eight grab samples, taken for the duration of an operating day, during periods of representative discharges including fish harvesting and/or unit cleaning or solids removal operations, and combined to form one representative sample. The monthly average must not exceed 10 mg/L, and the daily maximum must not exceed 15 mg/L.
3) Report average and daily maximum settleable solids from a composite sample, i.e., hourly grab samples, not to exceed eight grab samples, taken for the duration of an

operating day, during periods of representative discharges including fish harvesting and/or unit cleaning or solids removal operations, and combined to form one representative sample. The monthly average must not exceed 0.1 mL/L, and the daily maximum must not exceed 3.3 mL/L (DEQ 1998a).

A TSS load of 19.8 tons per year would be expected if the facility continuously discharged its daily maximum allowed TSS concentration. A solids load of 4.9 tons per year was estimated for the point source as determined from the monitoring during the TMDL study. The TSS load was converted to organic solids load by multiplying the TSS load by the estimated volatile solids fraction obtained from solids collected from the bottom of settling basins from three of the studied trout farms, 60 percent. The calculated organic solids load, therefore, is 5,848 pounds per year.

4.5.3 Nonpoint Source Loads

Sediment loads for the nonpoint sources in the affected stream riparian zone were estimated using the Revised Universal Soil Loss Equation (RUSLE) and a sediment delivery ratio of 0.9. The riparian zone was defined as a 300-foot land strip on each side of the stream segment. The RUSLE takes into account the vegetative cover, best management practices, slope, soil erodibility, and amount and intensity of rainfall. These factors are each assigned a numeric value, and the product of these values is multiplied by the riparian land acreage to determine an annual sediment load. Additional information about the RUSLE factors and an example calculation for the organic solids reference stream, Ingleside Spring Branch, can be found in Appendix I.

The estimated nonpoint source (NPS) sediment load was converted to the organic solid load by multiplying the NPS sediment load by the percent organic matter content of soil. Five percent organic matter content was used to account for the labile organic matter content originating from the nonpoint sources.

The Cockran Springs Branch riparian zone area (38 acres) is all in pasture. Visual assessment indicated that the NPS sediment and organic solids loads to Cockran Spring Branch mostly originates from areas with eroded streambanks, inadequate buffer, and cattle access to the stream. The estimated net sediment yield for the riparian area is 6.0 tons per year, and the riparian organic solids load is 600 pounds per year.

4.6 TMDL CALCULATION

Virginia does not currently have water quality criteria for organic solids. For this reason, a reference watershed approach was used to identify the TMDL target loads (See Section 3.4). The reference watershed approach was modified to consider only a part of the watershed—the stream riparian zone, a 300-foot land strip on each side of the stream segment.

For the TMDL calculations, Ingleside Spring Branch was used to set the target for the organic solids load. Ingleside Spring Branch was selected as the reference because it is a non-impaired, spring-fed stream in the Central Appalachian Ridge and Valley ecoregion, limestone sub-region with similar flow and water chemistry to Cockran Spring Branch. Additionally, in comparison to Mount Solon Spring Branch, Ingleside Spring Branch had more macroinvertebrate taxa, a higher density of organisms, and a lower mean HBI value, indicating that Ingleside Spring Branch is a slightly higher quality stream in terms of the benthic macroinvertebrate community (Appendix A).

Owing to differences in the stream lengths between the impaired segment and the reference stream, the target load estimate was adjusted to compensate for differences between the riparian area of Cockran Spring Branch and Ingleside Spring Branch. This adjustment was necessary because riparian size influences sediment delivery, and consequently organic solids load, to the stream.

By comparing Cockran Spring Branch to a similar non-impaired watershed (Ingleside Spring Branch) and allowing for a 5 percent margin of safety, the amount of organic solids loading that will meet the water quality objectives is 1,915 pounds per year. When this value is met, Cockran Spring Branch is expected to meet its aquatic life use.

The TMDL established for Cockran Spring Branch consists of a point source wasteload allocation (WLA), a nonpoint source load allocation (LA), and a margin of safety (MOS) (Table 4.3). The TMDL equation is as follows:

TMDL = WLA + LA + MOS

The WLA portion of this equation is the total loading assigned to point sources. The LA portion represents the loading assigned to nonpoint sources and includes the headwaters. The MOS is the portion of loading reserved to account for any uncertainty in the data and the computational methodology used for the analysis. An explicit MOS of five percent was used in the TMDL calculations to provide an additional level of protection for aquatic life.

Table 4.3 TMDL for Cockran Spring Branch

Watershed	Pollutant	TMDL (pounds/yr)	WLA (pounds/yr)	LA (pounds/yr)	MOS (pounds/yr)
Cockran Spring Branch	Organic Solids	2,016	1,556	359	101

4.7 LOAD ALLOCATION

Load allocations were assigned to each source category in the watershed based on information from the visual survey, knowledge of best management practices, and professional judgment. The spring loading represents the natural condition that would be expected to exist; therefore, the loading from the spring was not reduced. A load reduction of about 350 pounds per year for the pasture area could be achieved by creating a 50-foot buffer for 3,700 feet along the impaired stream. The remaining reduction would come from the point source. The organic solids allocation scenario for Cockran Spring Branch is presented in Table 4.4.

Table 4.4 Organic solids load allocations for Cockran Spring Branch

Source Category	Organic Solids Load Allocation (lbs/yr)	Percent Reduction
Headwaters (Spring)	9	0 %
Point Source (Trout Farm)	1,556	73 %
Nonpoint Sources (Pasture)	350	42 %
TMDL Load (Minus MOS)	1,915	

4.8 REDUCTION SCENARIO

The Best Management Practices (BMPs) described below should be sufficient to reduce the needed organic solids load to the TMDL target. The developed implementation plan should consider all BMPs and utilize the combination that works best for this impaired stream section. A summary of the TMDL implementation strategy and recommended BMPs are described in Section 13.2.

4.8.1 Point Source Reduction Scenario

Some Best Management Practices (BMPs), such as the use of high energy feed (42% protein and 16% fat content), are being used at the trout facility on Cockran Spring Branch. These implemented BMPs should be continued. Additional BMPs are needed to meet the TMDL organic solids load target of 1,556 pounds per year (73 percent reduction). General suggestions follow, but site-specific implementations plans should be developed for this trout facility.

The combined use of the suggested BMPs: 1) an improved end-of-raceway settling basin; 2) frequent cleaning of the sediment traps and settling basin; and 3) proper land application would be expected to reduce the existing organic solids effluent load (5,848 pounds per year) by 96 percent and allow only 234 pounds per year of organic solids from the trout farm to enter the stream. The TMDL goal is to reduce the existing load to 1,556 pounds per year of organic solids, a 73 percent reduction. Therefore, the combined use of the proposed BMPs is expected to meet the TMDL goal. A description of the proposed BMPs follows.

Settling Basin:

A settling area below the last raceway is currently used, but it should be redesigned to increase the efficiency in TSS and organic solids removal. It may also be redesigned to direct the effluent into a diversion channel when cleaning the basin. Boardman et al. (1998) found that sediment basins with 10-minute detention times are able to significantly reduce spike loadings but cannot reduce TSS concentrations during average flow conditions. Reductions during normal conditions require 20-minute detention times. Twenty-minute detention times resulted in 96 percent removal of TSS, and 30-minute detention times reduced TSS concentrations by almost 98 percent. Redesigning the settling basin to aim for efficiencies observed with the twenty-minute detention time in the pilot plant study is recommended.

The use of baffles in the settling basin that are spaced appropriately (to prevent scouring yet promote plug flow) is suggested as an economical way to increase flow length within the confines of a relatively small space so that solids may settle. The efficiency of the settling basin will depend on how clean it is kept. Effluent during the cleaning of a settling basin in this TMDL study (at another facility) had a TSS concentration of 53 mg/L when the basin was full (12 inches deep with solids) and a TSS concentration of 8 mg/L when the basin had only 0.5 inches of solids.

Off-line Settling Basins/Land Application:

Solids removed from sediment traps and settling basins must not be allowed to enter the impaired stream or tributaries to the impaired stream. These concentrated slurries should be treated in off-line settling basins or be land applied in such a way that runoff will not wash the solids to nearby streams. Because of space constraints at this location, an off-line settling basin may not be possible. Land application is therefore recommended as a way to prevent the collected solids from entering the impaired stream or it tributaries. Land application practices should be reviewed to make certain the collected solids are prevented from entering the impaired stream or it tributaries in runoff from the applied field.

4.8.2 Nonpoint Source Reduction Scenario

The Cockran Spring Branch riparian area (38 acres) is all in pasture. Visual assessment indicated that the nonpoint source (NPS) sediment load, and consequently the NPS organic solids load, to Cockran Spring Branch mostly originates from areas along an approximately 3,700-foot impaired stream length with eroded areas, inadequate buffer, and cattle access to the stream. The NPS required reduction of organic solids load from the current 600 pounds per year needs to be reduced to 350 pounds per year (42 percent reduction). To achieve the NPS required reduction of the organic solids load, the following Best Management Practices (BMPs) are proposed.

The pasture along the 3,700-foot impaired stream segment should be converted to a filter strip of grass and canopy. Installation of this BMP should improve the land cover condition, decrease runoff velocity, increase infiltration into the soil, and trap sediment before it enters the stream. In addition, fences and cattle stream crossings should be installed to reduce cattle access to stream. Fencing and crossing BMPs should improve eroded stream banks and prevent direct manure deposit in the stream. Literature supports the positive effects of buffer strips on preventing sediment transport to streams (Dillaha et al. 1986) and positive impacts of cover condition on Sediment Delivery Ratio (SDR) (Novotny and Olem 1994).

A BMP that consists of a 50-foot buffer grass strip with canopy (25 feet on each side of the stream) installed along the riparian area of the 3,700-foot section of the impaired stream will use 4.25 acres of the pasture. In the RUSLE calculation, the Management Practice (P) is reduced to 0.7 to compensate for the BMPs. The C factor (0.0028) is calculated as a weighted average for values in the pasture and buffer strip. Other RULSE factors remain the same (K = 0.34, LS = 1.3, R = 130); the SDR becomes 0.8. The BMPs result in 3.5 tons per year sediment yield (346 pounds per year organic solids yield), which meets the TMDL goal of 350 pounds per year (42 percent reduction).

5 LACEY SPRING BRANCH TMDL

5.1 INTRODUCTION

In 1998, an unnamed tributary, called Lacey Spring Branch, was declared impaired for failing to support aquatic life. The impaired segment begins at the discharge of a trout farm and continues downstream for 0.2 miles to the confluence with Smith Creek. The trout farm effluent was suspected as the cause of the impairment, but the exact pollutant or pollution causing the impairment was not identified. The stream received a priority of "medium" for not/partially supporting the aquatic life use (DEQ 1998b).

5.1.1 Watershed Background

Lacey Spring Branch, a first-order stream, begins with a perennial spring and flows approximately 0.2 miles before discharging into Smith Creek, a tributary of the North Fork Shenandoah River. Waters from the Shenandoah River Basin eventually flow into the Chesapeake Bay. The Lacey Spring Branch watershed is located in Rockingham County, Virginia and is part of the Shenandoah River hydrologic unit number 02070006 with watershed identification code of VAV-B47R.

The benthic macroinvertebrate surveys of the impaired segment were compared to surveys taken from a reference stream to obtain the impaired status. The reference stream is a part of Mount Solon Spring Branch. The reference stream is located in Augusta County, Virginia. Like the impaired stream, the reference stream is in the Central Appalachian Ridge and Valley ecoregion, limestone sub-region.

Watershed delineation for both the impaired stream segment and the reference stream followed natural topographic drainage divides (Appendix E). The watershed area for Lacey Spring Branch is about 335 acres, and the watershed area for the reference stream, Mount Solon Spring Branch, is approximately 220 acres. The land use of the Lacey Spring Branch watershed is pastureland (58%), residential (28%), roadways (9%), and mixed forest (5%). Route 11, Route 806, and Interstate-81 are the main roads that transect the watershed. The land use for the watershed of Mount Solon Spring Branch is residential (52%), pastureland (46%), and deciduous forests (2%). Water runoff from Routes 731 and 747, as they transect the watershed, drains to Mount Solon Spring Branch.

5.2 BENTHIC MONITORING

5.2.1 DEQ Benthic Monitoring

DEQ's biological monitoring on May 31, 1995 (using Rapid Bioassessment Protocol (RBP) II) indicated severe benthic impairment of Lacey Spring Branch. The affected station was established on Lacey Spring Branch about 150 yards downstream of a trout farm discharge, and just upstream of the culvert that passes beneath Interstate-81. This site had five families of relatively pollution tolerant organisms. Almost 90 percent of the organisms belonged to either the Asellidae (sow bugs) or the Lymnaeidae (pulmonate snails). These organisms are scavengers and indicate enriched waters (Bolgiano 1995b). Additional macroinvertebrate sampling in August 2000, found eight families at the benthic sampling location, with the Asellidae and Hydrobiidae (operaculate snails) dominating the sample. No Lymnaeidae were collected in the 2000 sample (Van Wart 2000b).

Additional benthic macroinvertebrate surveys were conducted on May 31, 1995 on Smith Creek: one survey upstream of the confluence with Lacey Spring Branch and another 0.24 miles downstream of the confluence. Both stations on Smith Creek were judged to be "moderately impaired," but a comparison of the two stations suggested that Lacey Spring Branch has a negative impact on the stream. In comparing the Smith Creek downstream site with the upstream site, there was a decrease in the number of represented Tricoptera families (pollution-intolerant families). The ratio of shredders to total individuals was lower (suggesting more of an ecological imbalance) at the downstream site (Bolgiano 1995b).

5.2.2 TMDL Benthic Monitoring

As a part of the TMDL study, it was recommended that a more in-depth benthic study be conducted to provide additional data for further evaluation of the impaired status of the streams (Appendix A).

Mount Solon Spring Branch (Reference Stream):

The benthic community at Mount Solon Spring Branch was composed of 19 taxa in the samples (Appendix A). Only three of the taxa were Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (stoneflies) (EPT) taxa. Isopods were the most common taxon, but overall no single or even a few taxa dominated the community in terms of abundance. Four taxa of snails were found; the two taxa of pleurocerid snails were fairly common whereas the other two taxa occurred only in one sample each. The abundance of isopods made the relative abundance of shredders the highest of the functional feeding groups. The HBI value of 7.3 reflected a community composed of "moderately tolerant" to "tolerant" taxa.

Lacey Spring Branch:

The benthic community at Lacey Spring Branch had a HBI value of 7.8 and was significantly different from its reference site (Mount Solon Spring Branch) in only one metric. Only eight taxa occurred in the samples from this site, mean taxa richness being the only significantly different metric. Only one EPT taxon was found. Mean density was nearly three times higher than at the reference site, but high variability among replicates led to no statistically significant difference with the reference site for this metric. The benthic community was dominated in numbers by isopods, oligochaetes and hydrobiid snails, similar to the reference site; however, there were fewer rare taxa here than at the reference site, leading to the difference in mean taxa richness. Community composition was similar to that found during previous DEQ benthic surveys. Lacey Spring Branch may be impaired based on the low species richness and only one EPT taxon occurring in the samples.

5.3 VISUAL SURVEY

The objective of the visual survey was to document environmental conditions with potential to affect the benthic community. The visual survey involved observing and cataloging water and land conditions, land and water uses, and the changes that take place along defined stream segments (Appendix F).

Mount Solon Spring Branch (Reference Stream):

Mount Solon Spring is located in the town of Mount Solon. A concrete wall impounds the spring. The visual survey included the area from where the water exited the impoundment to a length of less than 200 feet. The water going over the spillway enters a pipe and flows underground for approximately 75-100 feet. The spring water enters the stream from a concrete pipe. The effluent from a small sewage treatment facility for a building with three apartments enters the stream on the left through a four-inch plastic pipe. The left stream bank is mostly lawn, and the right side is a wetland area with some trees. Three trash piles were documented: residential trash in and by the water as it exits the underground pipe, a few tires on the left side near the sewage treatment discharge, and about 120 square feet of ground covered by large sheets of scrap metal by the stream and close to the road. A drainage ditch along Route 731 (Natural Chimney's Road) feeds to the stream. The lower boundary of the visual survey occurred where the stream flows through three three-foot metal corrugated pipes to pass under Route 731.

Lacey Spring Branch:

The headwaters of Lacey Spring Branch are a perennial spring east of U.S. Route 11 in Rockingham County. The stream flows through a series of trout rearing units. The visual survey included the impaired segment of Lacey Spring Branch from the trout facility outfall to the stream's confluence with Smith Creek.

Observed environmental conditions along Lacey Spring Branch include: channel alterations, inadequate buffer zones, livestock access to the stream, erosion sites, mats of periphyton, an outfall, and trash piles. In the upper reaches of the stream, one point discharge site was observed: the trout farm effluent. Thick mats of periphyton covered the substrate for the first several 100 yards of the impaired segment.

Three channel alterations were documented during the visual survey. The first was associated with Interstate-81. The stream was funneled through two concrete underpasses. Each structure was made of two four-feet by six-feet boxed culverts. After going under I-81, the stream flows through a second concrete culvert to pass under Route 986 (Stony Point Road). The third channel alteration was just upstream of Lacey Spring Branch's confluence with Smith Creek. The stream was diverted through several pipes for a gravel road to cross.

The stream is affected by over 1,000 feet of inadequate riparian buffer, where the stream lacks the pollution filtration and shading provided by a forested buffer. In the upper section of the stream, lawns on the left bank and a grassy field on the right bank constricted the buffer. Some trees were present but did not provide adequate shading or protection to the stream. Below the residential area, the left bank turned to pastureland. A few trees were present but not enough for adequate buffer classification. On the east side of Interstate-81, the stream flows through a pasture field to Smith Creek.

Livestock with access to the stream were observed on both sides of the interstate. The field on the west side (upstream site) had sheep and the east side had beef cattle. Stream bank erosion was observed in conjunction with livestock access. Another erosion site was localized to a residential home. The erosion site was 50 feet in length with a bank height of 12 feet. The erosion was causing the stream bank to downcut.

A single trash pile was documented on the right stream bank. It was confined to a small area and consisted of tires and other small residential type trash. A large empty metal drum in the stream was observed just below the trash pile. Its former contents were unknown, but the bottom had rusted, and the contents had been displaced with water.

5.4 FISH SURVEY

Visual observations indicated that numerous fish in Lacey Spring Branch may impact the stream’s benthic macroinvertebrate community. A fish survey was conducted to determine the likely impact of fish predation. See Appendix C for more information. Only a single species of fish, introduced rainbow trout, was collected in Lacey Spring Branch. The relatively low abundance of trout (5.3 fish per minute) in Lacey Springs Branch makes it unlikely that fish predation could bias significantly the RBP assessments. Based on these findings, the advisory panel concluded that fish predation is unlikely to be a stressor in this stream.

5.5 PHYSICAL/CHEMICAL MONITORING

5.5.1 DEQ and Other Physical/Chemical Monitoring

A TSS load of 7.4 tons per year was estimated from the discharge monitoring reports from October 2000 to March 2001 and July 2001 to December 2001 for the trout farm on Lacey Spring Branch. The highest flows from this data were obtained from July to September 2001, the period when most of the TMDL data were collected. All the other flows were considerably lower.

Boardman et al. (1998) obtained inlet, within farm, and outlet water quality data for three trout farms in Virginia from September 1997 to April 1998 on a bi-monthly basis. Their TSS findings are shown in Table 5.1. Using the average TSS concentrations from the farm effluents with the lowest and highest TSS concentrations (Farm A, 3.0 mg/L; Farm C, 5.8 mg/L) and a spring flow of 7.21 cfs (comparable to the spring flow in this study), a TSS load of 21.3 tons per year to 41.2 tons per year could be expected.

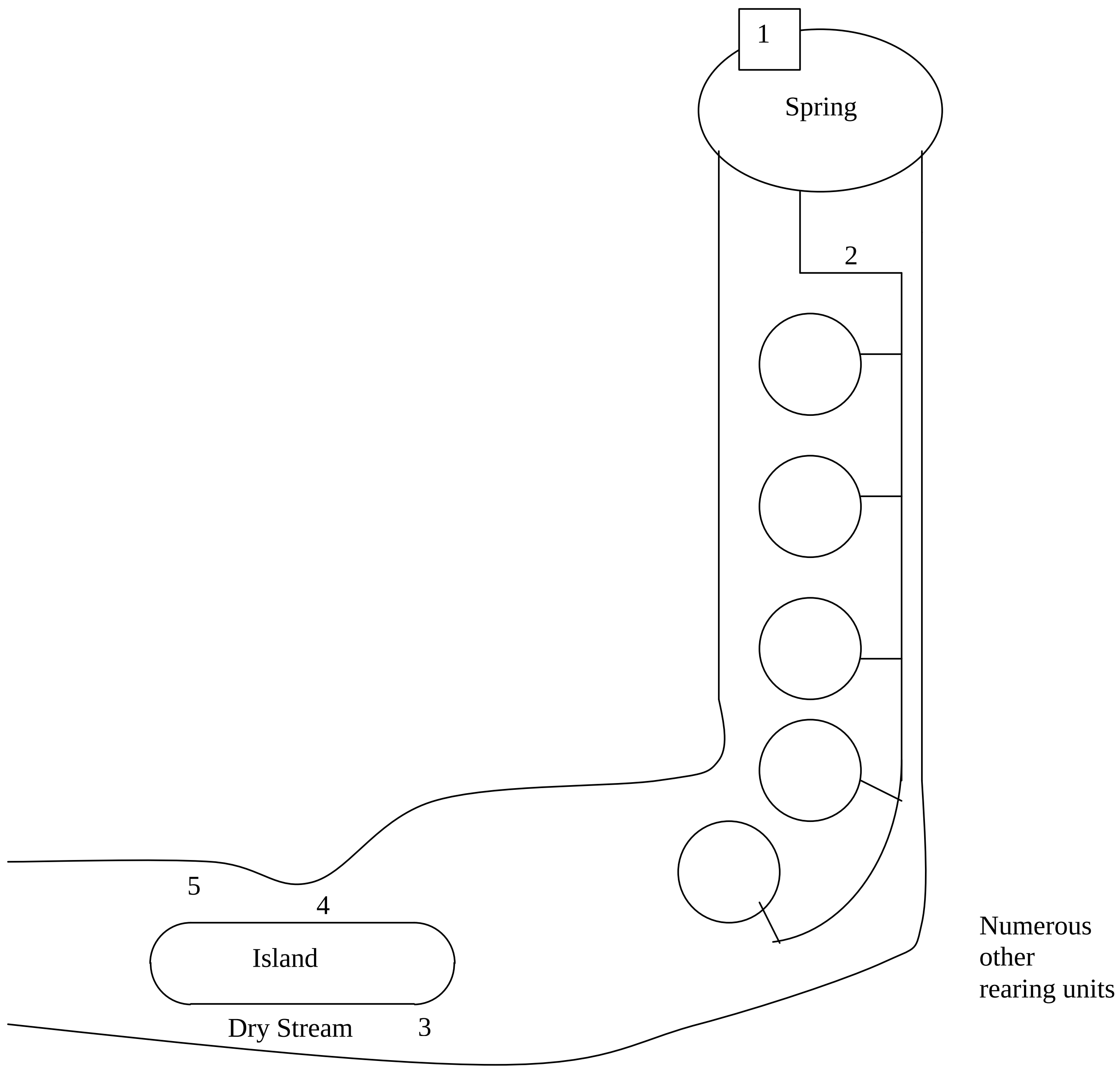
Table 5.1 Total suspended solids concentrations for trout farms A, B, and C. "Within Farm" refers to data obtained from the end of all active raceways in each farm.

	Farm A			**Farm B**			**Farm C**		
(mg/L)	Inlet	Within Farm	Outlet	Inlet	Within Farm	Outlet	Inlet	Within Farm	Outlet
TSS range	0-1.1	0-30.4	0.8-6.0	0-1.8	0-43.7	1.5-7.5	0-1.5	0-28	4.1-62
TSS average	0.2	3.9	3.2	0.5	5.3	3.9	0.3	7.1	6.1*

* Two outliers removed for calculation of the average

5.5.2 TMDL Physical/Chemical Monitoring

Water sampling for Lacey Spring Branch for the TMDL study occurred between August 21, 2001 and January 26, 2002. Samples were collected from the spring, the side stream (which went dry before joining with the main trout farm effluent outfall), the main trout farm outfall, the benthic sampling location, and the end of the impairment (Figure 5.1). Flow was also obtained at the trout farm outfall, benthic sampling location, and near the end of the impairment. Sampling procedures are described in Appendix G.



Lacey Spring-Trout Farm Facility

1. Spring House (sample site)
2. Headwaters (sample site)
3. Side Stream (sample site)
4. Trout Farm Main Outfall (sample site)
5. Flow Measurement Site

Figure 5.1 Diagram of sample collection sites and stream flow measurement site for the trout farm facility on Lacey Spring Branch. Not drawn to scale.

The flow was variable during the sampling period, averaging 7.2 cfs for the two estimates taken in August and 2.7 cfs for the January sampling. A flow of 7.2 cfs was used in the load calculation because including the low flow measurement would bias the average towards being lower than what stakeholders describe as normal for this stream.

Thirty-one samples were taken from the trout facility outfall during periods of feeding, harvesting, and no apparent farm activity. Only one sample had TSS concentrations higher than 5.00 mg/L (Appendix H). The TSS concentrations ranged from 0.19 to 6.07 mg/L, with a mean of 2.94 mg/L. A total solids load of 9.6 tons per year was estimated for the point source from an average of the TMDL study samples from the trout farm outfall.

5.6 POLLUTION SOURCES

Table 5.2 presents the existing average annual organic solids load for Lacey Spring Branch.

Table 5.2 Existing organic solids loading in Lacey Spring Branch

Source Category	Organic Load (pounds per year)	Percent of Total Load
Headwaters (Spring)	1,127	8.5 %
Point Source		
Elementary School	414	3.1 %
Trout Farm	11,481	86.2 %
Nonpoint Source		
Pasture/Grassy Field	110	0.8 %
Roads/Grassy Slopes	155	1.2 %
Residential	38	0.3 %
Total Existing Load	13,325	100 %

5.6.1 Natural Background Loads

Water samples taken from the headwaters of Lacey Spring on four occasions had an average TSS concentration of 1.59 mg/L (range: 1.00 to 2.05 mg/L), giving the natural background from the spring a TSS load of 11.3 tons per year. The organic solids load was estimated as 5 percent of the TSS load because nonpoint source pollution is believed to influence the headwaters. This calculation yields an organic solids load of 1,127 pounds per year. This was considered a conservative estimate because the sampling occurred during dry conditions, and trout farm personnel report that the spring waters are more turbid under wet conditions.

5.6.2 Point Source Loads

Two point sources were documented in the Lacey Spring Branch watershed. One source is the sewage treatment plant for an elementary school that flows into a drainage ditch that eventually flows into Lacey Spring Branch, and the other is effluent from a trout farm located adjacent to the spring.

Elementary School:

The school holds permit VA0077399. An instantaneous maximum discharge limit for TSS is 30 mg/L. Inspection of the discharge monitoring reports from January 1999 to December 2001 indicates that the school is in compliance with its permit.

Effluent from the school enters a drainage ditch that flows for about a half mile to Lacey Springs Branch. The ditch enters the impaired stream approximately 700 feet from the headwaters or immediately upstream of the I-81 crossing. The ditch was dry during both sampling periods.

Using the permit flow of 0.0075 million of gallons per day (MGD) and average permitted limit of 30 mg/L of TSS yields an annual load of 0.3 tons per year of solids from the school's sewage treatment. The average organic content of domestic sewage is 70 percent (Metcalf and Eddy 1991), which gives an organic solids load of 414 pounds per year. This load estimate is probably higher than what might be expected, depending on the effectiveness of the treatment.

Trout Farm:

The other point source is an aquaculture facility that raises trout for processing. Processing takes place at the facility, but the fish processing wastewater is hauled to the local sewage treatment plant (STP) for treatment and does not enter Lacey Spring Branch.

The trout farm holds a general permit (Virginia Pollutant Discharge Elimination System Permit VAG131005) that requires quarterly monitoring of discharge flow, total suspended solids, and settleable solids. According to the general permit, the facility should monitor the effluent once every three months for the following parameters:

1) Estimate flow (million gallons per day, MGD) at the time of the sampling. There is no effluent limit for flow.
2) Report monthly average and daily maximum total suspended solids (TSS) from a composite sample, i.e., hourly grab samples, not to exceed eight grab samples, taken for the duration of an operating day, during periods of representative discharges including fish harvesting and/or unit cleaning or solids removal operations, and combined to form one representative sample. The monthly average must not exceed 10 mg/L, and the daily maximum must not exceed 15 mg/L.

3) Report average and daily maximum settleable solids from a composite sample, i.e., hourly grab samples, not to exceed eight grab samples, taken for the duration of an operating day, during periods of representative discharges including fish harvesting and/or unit cleaning or solids removal operations, and combined to form one representative sample. The monthly average must not exceed 0.1 mL/L, and the daily maximum must not exceed 3.3 mL/L (DEQ 1998a).

A load of 106.5 tons per year of TSS would be expected if the facility continuously discharged its daily maximum allowed TSS concentration. A calculated TSS load of 9.6 tons per year as measured by the TMDL study sampling was used for the contributions from the trout facility: TSS Load at Trout Farm Outfall (20.84 tons per year) - TSS Load from the Spring (11.27 tons per year) = 9.57 tons per year. The TSS load was converted to organic solids load by multiplying the TSS load by the volatile solids fraction obtained from solids collected from the bottom of settling basins from three of the studied trout farms, 60 percent. This calculation gave an organic solids load of 11,481 pounds per year.

5.6.3 Nonpoint Source Loads

Sediment loads for the nonpoint sources in the affected stream riparian zone were estimated using the Revised Universal Soil Loss Equation (RUSLE) and a sediment delivery ratio of 0.9. The riparian zone was defined as a 300-foot land strip on each side of the stream segment. The RUSLE takes into account the vegetative cover, best management practices, slope, soil erodibility, and amount and intensity of rainfall. These factors are each assigned a numeric value, and the product of these values is multiplied by the riparian land acreage to determine an annual sediment load. Additional information about the RUSLE factors and an example calculation for Ingleside Spring Branch, the organic solids load reference, can be found in Appendix I.

The Lacey Spring Branch riparian zone area (18 acres) is 47% pasture/grassy fields, 41% roads with their grassy slopes, and 12% residential.

The estimated nonpoint source (NPS) sediment load was converted to the organic solid load by multiplying the NPS sediment load by the percent organic matter content of soil. Five percent organic matter content was used to account for the labile organic matter content originating from the nonpoint sources. Land use, sediment yield, and organic load within the 600-foot riparian zone (18 acres) for Lacey Spring Branch are described in Table 5.3.

Table 5.3 Land use, area, sediment yield, and organic solids load for the riparian area of Lacey Spring Branch.

Land Use	Percent of Area	Sediment Yield (tons/year)	Organic Solids Load (pounds/year)
Pasture/Grassy Field	47 %	1.1	110
Roads/Grassy Slopes	41 %	1.5	155
Residential	12 %	0.4	38
Total	**100 %**	**3.0**	**303**

5.7 TMDL CALCULATION

Virginia does not currently have water quality criteria for organic solids. For this reason, a reference watershed approach was used to identify the TMDL target loads (See Section 3.4). The reference watershed approach was modified to consider only a part of the watershed—the stream riparian zone, a 300-foot land strip on each side of the stream segment.

Ideally, the benthic reference site would be used to set the organic solids target because the characteristics, particularly the chemical/physical characteristics, would be expected to be most similar. Using the benthic reference stream, Mount Solon Spring Branch, as the organic solids load reference for Lacey Spring Branch would result in a target organic solids load of 366 pounds per year. The headwaters (spring) of Lacey Spring Branch yield 1,127 pounds per year of organic solids. Even after eliminating all point sources and nonpoint sources along Lacey Spring Branch, the load from the spring would need to be reduced by two-thirds (67 percent) to meet the Mount Solon based target. It was concluded, therefore, that Mount Solon Spring Branch is not a suitable organic solids target for Lacey Spring Branch.

Ingleside Spring Branch was used to set the organic solids target. The water chemistry of Lacey Spring Branch is more similar to Ingleside Spring Branch than it is to Mount Solon Spring Branch. Ingleside Spring Branch is a non-impaired, spring-fed stream in the Central Appalachian Ridge and Valley ecoregion, limestone sub-region. In comparison to Mount Solon Spring Branch, Ingleside Spring Branch had more macroinvertebrate taxa, a higher density of organisms, and a lower mean HBI value, indicating that Ingleside Spring Branch is a slightly higher quality stream in terms of the benthic macroinvertebrate community (Appendix A).

Owing to differences in the stream lengths between the impaired segment and the organic solids reference stream, the target load estimate was adjusted to compensate for differences between the riparian area of Lacey Spring Branch and Ingleside Spring Branch. This adjustment was necessary because riparian size influences sediment delivery, and consequently organic solids load, to the stream.

By comparing Lacey Spring Branch to a non-impaired watershed (Ingleside Spring Branch, See Section 3.7) and allowing for a 5 percent margin of safety, the amount of organic solids loading that will meet the water quality objectives is 909 pounds per year.

The TMDL established for Lacey Spring Branch consists of a point source wasteload allocation (WLA), a nonpoint source load allocation (LA), and a margin of safety (MOS)(Table 5.4). The TMDL equation is as follows:

TMDL = WLA + LA + MOS

The WLA portion of this equation is the total loading assigned to point sources. The LA portion represents the loading assigned to nonpoint sources and includes the loads from the spring (headwaters). The MOS is the portion of loading reserved to account for any uncertainty in the data and the computational methodology used for the analysis. An explicit MOS of five percent was used in the TMDL calculations to provide an additional level of protection for aquatic life.

Table 5.4 TMDL for Lacey Spring Branch

Watershed	Pollutant	TMDL (pounds/yr)	WLA (pounds/yr)	LA (pounds/yr)	MOS (pounds/yr)
Lacey Spring Branch	Organic Solids	957	680	229	48

5.8 LOAD ALLOCATION

Load allocations were assigned to each source category in the watershed based on information from the visual survey, knowledge of best management practices, and professional judgment (Table 5.5). Loadings from certain source categories were allocated according to their existing loads. For instance, converting Interstate-81 and other roads to forest area is not attainable. The loading from the elementary school is small in comparison to the total load (less than four percent) and likely to have limited impact on Lacey Spring Branch given its small flow and distance from the stream (0.5 miles) so no reductions were allocated to this source.

Table 5.5 Organic solids load allocations for Lacey Spring Branch

Source Category	Organic Solids Load Allocation (lbs/yr)	Percent Reduction
Headwaters (Spring)	47	96 %
Point Source		
Elementary School	414	0 %
Trout Farm	222	98 %
Nonpoint Source		
Pasture/Grassy Field	52	53 %
Roads/Grassy Slopes	155	0 %
Residential	19	50 %
TMDL Load (Minus MOS)	909	

5.9 LOAD REDUCTION SCENARIO

The Best Management Practices (BMPs) described below should be sufficient to reduce the needed organic solids load to the TMDL target. The developed implementation plan should consider all BMPs and utilize the combination that works best for this impaired stream section. A summary of the TMDL implementation strategy and recommended BMPs are described in Section 13.2.

5.9.1 Point Source Reduction Scenario

Trout Farm:

Some Best Management Practices (BMPs), such as the use of high energy feed (40-48% protein and 10-14% fat content), are being used at the trout facility on Lacey Spring Branch. These implemented BMPs should be continued. Additional BMPs are needed to meet the TMDL organic solids load target (98 percent reduction). General suggestions follow, but site-specific implementations plans should be developed for this trout facility.

The circular rearing units used at the trout facility on Lacey Spring Branch could be modified to create a double drain design. In such designs, Summerfelt (1998) found that the existing bottom drain removes 90 to 95 percent of the solids with about five to ten percent of the operating flow rate. The remaining water, which is considered to be 90-percent clean, exits a drain placed near the surface or at mid-depth. This "clean" water can be mixed with five to ten percent spring water and be recirculated through the system. Such a design may prove practical at this site, particularly if spring levels remain low.

Converting the facility into a partial recirculation system would use less spring water and would concentrate the solids, making them more easily and efficiently removed from the effluent. The effluent removed from the rearing unit could be treated with microscreens, which have solids removal efficiencies up to 80 percent. Microscreens, however, can be expensive to operate so other alternatives should be explored (Boardman et al. 1998). Alternatively, the five to ten percent volume of water to be treated could be pumped to a tank for settling as is currently being considered by farm personnel. The settled solids could than be composted or land applied.

If a partial recirculation system is not desired, the current settling basin at this facility could also be converted into a constructed wetland to receive the 90-percent "clean" water. More research would be needed before implementing such a plan because solids removal by the wetlands would need to be about 60 to 80 percent effective to meet the TMDL target. Wetlands used in conjunction with another treatment option may provide the desired reduction in organic solids loads.

5.9.2 Nonpoint Source Reduction Scenario

Visual assessment and results of the physical/chemical monitoring indicated that the nonpoint source (NPS) sediment load, and consequently the NPS organic solids load, to Lacey Spring Branch originate from the following areas: the spring, a pasture where cattle have access to the stream; a pasture where sheep have access to the stream; a grassy field; the roads and their associated grassy slopes, and an eroded slope within a residential yard. No BMPs are recommended for the roads and their grassy slopes, but BMPs are suggested for the other nonpoint sources.

Spring:

The spring waters have high TSS concentrations relative to most springs and therefore have a high organic solids load. One of two approaches could be taken in regard to reducing loads from the spring. One option would be to implement BMPs for the point sources and nonpoint sources along Lacey Spring Branch and see if benthic restoration occurs with these changes alone. Secondly, a study could be conducted to find the source waters for this spring and implement BMPs along the streams and sinkholes in the identified watersheds.

Pasture and Grassy Field:

The NPS reduction of organic solids load from the current 110 pounds per year in the pasture/grassy field area needs to be reduced to 52 pounds per year (53 percent reduction). To achieve the NPS required reduction of the organic solids load the following Best Management Practices (BMPs) are proposed.

Filter strips of grass and canopy should be installed along 550 feet of the grassy field, 250 feet on the other side of the stream where the sheep pasture is located and along both sides of the cattle pasture on the east side Interstate-81. In addition, fencing should be installed to keep livestock out of the stream. The BMPs should improve the land cover condition, decrease runoff velocity, increase infiltration into the soil, and trap sediment before it enters the stream. Literature supports the positive effects of buffer strips on preventing sediment transport to streams (Dillaha et al. 1986) and positive impacts of cover condition on Sediment Delivery Ratio (SDR) (Novotny and Olem 1994).

In the cattle pasture, sheep pasture, and grassy field, a BMP that consists of a 100-foot buffer grass strip and canopy along the riparian area of the impaired stream segment will use a total of 3.1 acres of the total pasture/grassy area in the riparian area (8.6 acres). The BMPs will result in 0.5 tons per year sediment yield (52 pounds per year organic solids yield), which is equivalent to the 53 percent reduction needed.

The management practices affect some of the RUSLE factors. The Management Practice (P) factor is reduced to 0.7 to compensate for the BMPs, and the C factor (0.0023) is calculated as a weighted average for values in the pasture/grassy field and buffer strip. The other RULSE factors remain the same (K = 0.36, LS = 1.0, R = 130), and the SDR becomes 0.8.

Residential Area:

The organic solids load in the residential area should be reduced from 38 pounds per year to 19 pounds per year (50 percent reduction). In the residential area, an area equivalent to 0.8 acres could be converted to canopy and would result in 0.2 tons per year sediment yield (19 pounds per year organic solids yield), which is equivalent to the 50 percent reduction needed.

The management practice affects some of the RUSLE factors. The Management Practice (P) value is reduced to 0.7 to compensate for the BMP, and the C factor (0.0023) is calculated as a weighted average for values in the residential area and buffer strip set for good cover condition. Other RUSLE factors remain the same (K = 0.37, LS = 1.5, R = 130), and the SDR is set to 0.8.

6 ORNDORFF SPRING BRANCH TMDL

6.1 INTRODUCTION

In 1998, an unnamed tributary, called Orndorff Spring Branch was declared impaired for failing to support aquatic life (DEQ 1998b). The impaired segment is 0.15 miles in length, begins at the outfall of a trout facility, and continues to the confluence with Cedar Creek. The effluent from the trout facility was suspected as the cause of the impairment, but the exact pollutant or pollution causing the impairment was not identified. The stream received a priority of "medium" for not/partially supporting the aquatic life use.

6.1.1 Watershed Background

The impaired stream is a first-order stream with two perennial springs as the headwaters. Orndorff Spring Branch discharges into Cedar Creek, which drains to the North Fork Shenandoah River. Waters of the Shenandoah River Basin flow into the Chesapeake Bay. The Orndorff Spring Branch watershed is part of the Shenandoah River hydrologic unit number 02070006 with watershed identification code of VAV-B52R. It is located in the Central Appalachian Ridge and Valley ecoregion in Shenandoah County, Virginia.

The benthic macroinvertebrate surveys of the impaired segment were compared to surveys taken from a reference stream to obtain the impaired status. The reference stream is a part of Ingleside Spring Branch. The water from Ingleside Spring feeds two channels: one side flows through a trout rearing facility and the other flows through an open field. The reference stream is located in the section that flows through the open field. Ingleside Spring Branch is located in Rockbridge County, Virginia. Like the impaired stream, the reference stream is in the Central Appalachian Ridge and Valley ecoregion, limestone sub-region.

Watershed delineation for both the impaired stream segment and the reference stream followed natural topographic drainage divides (Appendix E). The watershed area for Orndorff Spring Branch is about 8 acres, while the watershed area for the reference stream, Ingleside Spring Branch, is approximately 50 acres. The land use of the Orndorff Spring Branch watershed is mixed forests (69%), deciduous forests (16%), roadways (14%), and cropland (1%). The land use for the watershed of Ingleside Spring Branch is pastureland (99%) and a road, Route 612 (1%).

6.2 BENTHIC MONITORING

6.2.1 DEQ Benthic Monitoring

DEQ's biological monitoring on May 1, 1996 (using Rapid Bioassessment Protocol (RBP) II) indicated severe benthic impairment on Orndorff Spring Branch. Complete absence of functional feeding groups and whole orders of insect families suggested severe imbalance. The community was dominated by the Chironomidae (midges), which are fairly pollution-tolerant (Bolgiano 1996a).

On May 1, 1996, DEQ also monitored three stations on Cedar Creek that bracket two fish facilities: the one on Orndorff Spring Branch and an unpermitted facility. Stations below the fish facilities had benthic communities indicative of slightly impaired benthic assemblages.

6.2.2 TMDL Benthic Monitoring

As a part of the TMDL process, it was recommended that a more in-depth benthic study be conducted to provide additional data for further evaluation of the impaired status of the streams. See Appendix A for more information.

Ingleside Spring Branch (Reference Stream):

The benthic community at Ingleside Spring Branch was composed of a variety of species, 23 taxa occurring in the five replicate samples combined and five of those being Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (stoneflies) (EPT) taxa. Scrapers dominated the community because of the abundance of the snail *Somatogyrus,* by far the most abundant taxon at the site. The mean HBI value of 6.2 reflected a community composed of primarily moderately tolerant taxa. Few taxa with HBI values indicative of highly tolerant species were common at the site, whereas a number of taxa that have low HBI values, indicating intolerant species, were common.

Orndorff Spring Branch:

The benthic community at Orndorff Spring Branch was significantly different from its reference site (Ingleside) in five of the seven tested metrics. Although mean density was over 45,000 individuals/m^2 at this site compared to about 25,000 individuals/m^2 at the reference site, there was no statistically significant difference in this metric between the two sites. The two EPT metrics were significantly different from the reference site, reflecting no EPT taxa occurring in the samples from this site. Oligochaetes, a planorbid snail, isopods and planaria dominated the benthic community. All of these taxa are quite tolerant species, as are several other taxa common at the site. Community composition was similar to that found by previous DEQ benthic surveys except that chironomids were not as important a component of the community as in the

DEQ surveys. The mean HBI value of 8.1 was significantly greater than at the reference site, indicating a shift in community composition to more tolerant species. The percent abundance of scrapers and shredders were significantly different from the reference site, caused by the changes in species composition to the more tolerant species.

The benthic community in Orndorff Spring Branch was clearly different from that expected in a reference stream. It was composed of far more oligochaetes and planaria than would occur in a reference stream, and the species of snails expected in a reference stream likely would not be *Physella* and *Gyraulus*, which are quite tolerant of enriched conditions. The total lack of EPT taxa also is not expected, although the substrate was not particularly conducive to supporting many EPT taxa.

6.3 VISUAL SURVEY

The objective of the visual survey was to document environmental conditions with potential to affect the benthic community. The visual survey involved observing and cataloging water and land conditions, land and water uses, and the changes that take place along defined stream segments (Appendix F).

Ingleside Spring Branch (Reference Stream):

The visual survey of Ingleside Spring Branch encompassed approximately 500 feet of the stream. The survey began just below the spring and continued downstream (on the side not used for the trout farm) to the confluence with North Buffalo Creek. Adequate riparian vegetation (e.g., tree canopy) was lacking for the entire stream length on both banks. The land adjacent to the stream consisted of the trout farm (not the trout farm under study) on the left bank and an open field on the right bank. Livestock does not have access to the stream. One channel alteration was documented: three metal pipes to allow flow under a gravel drive that crosses the stream.

Orndorff Spring Branch:

The headwaters of Orndorff Spring Branch are two perennial springs. The main spring is located on the west side of Route 600, and passes under the road through a pipe to the trout facility. The secondary spring is located on the east side of Route 600. Water from the springs is piped to the trout farm. The stream flows through a series of raceways for rearing trout and a catch-out pond. Water from a wet weather spring discharges into Orndorff Spring Branch just below the trout farm effluent outfall. Orndorff Spring Branch flows about 0.15 miles to Cedar Creek.

The effluent from the trout farm was the only point discharge observed. Periphyton was seen growing on the substrate of the impaired stream. One erosion site was observed. It was reported to be 20 feet in length and about six feet in height. It was located at the bend of a steep slope in a forested area and was believed to be caused by natural erosion processes.

6.4 PHYSICAL/CHEMICAL MONITORING

6.4.1 DEQ and Other Physical/Chemical Monitoring

An average of the discharge monitoring reports (DMRs between October 1998 to December 2001) obtained from DEQ yielded a solid load estimate of 2.4 tons per year based on total suspended solids (TSS) concentrations and flow estimates.

Boardman et al. (1998) obtained inlet, within farm, and outlet water quality data for three trout farms in Virginia from September 1997 to April 1998 on a bi-monthly basis. Their TSS findings are shown in Table 6.1. Using the average TSS concentrations from the farm effluents with the lowest and highest TSS concentrations (Farm A, 3.0 mg/L; Farm C, 5.8 mg/L) and a spring flow of 2.08 cfs (comparable to the spring flow in this study), a TSS load of 6.1 tons per year to 11.9 tons per year could be expected.

Table 6.1 Total suspended solids concentrations for trout farms A, B, and C. "Within Farm" refers to data obtained from the end of all active raceways in each farm.

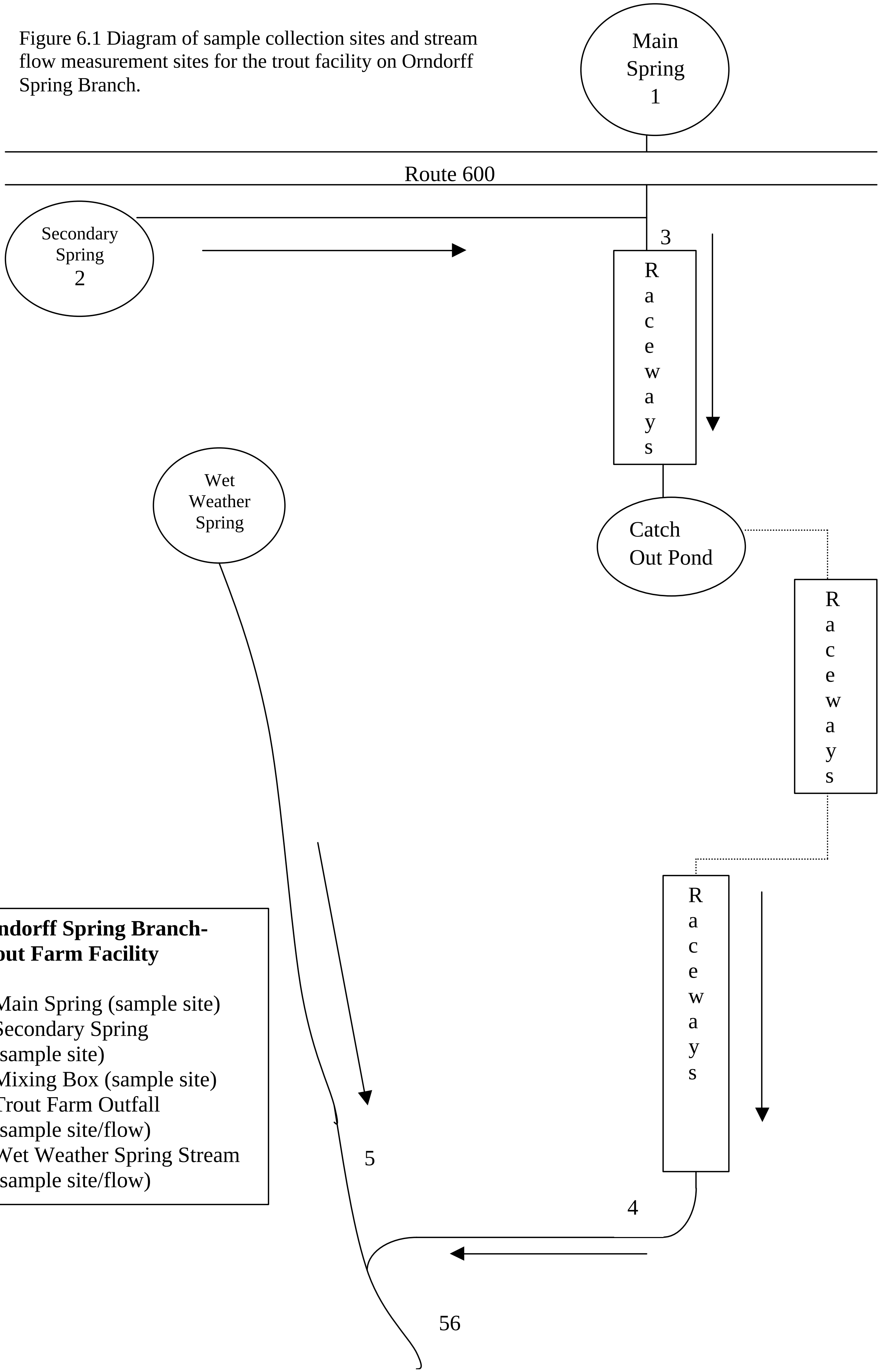
	Farm A			**Farm B**			**Farm C**		
(mg/L)	Inlet	Within Farm	Outlet	Inlet	Within Farm	Outlet	Inlet	Within Farm	Outlet
TSS range	0-1.1	0-30.4	0.8-6.0	0-1.8	0-43.7	1.5-7.5	0-1.5	0-28	4.1-62
TSS average	0.2	3.9	3.2	0.5	5.3	3.9	0.3	7.1	6.1*

*Two outliers removed for calculation of the average

6.4.2 TMDL Physical/Chemical Monitoring

Sampling at the trout facility for the TMDL study occurred from July 23-July 28, 2001 and on January 26, 2002. Samples were collected from the main spring, secondary spring, mixing box for the trout farm, trout farm outfall, wet weather spring stream, and the benthic sampling location (Figure 6.1). Samples were collected during the various activities that take place at the farm as described in Appendix G.

Figure 6.1 Diagram of sample collection sites and stream flow measurement sites for the trout facility on Orndorff Spring Branch.



Orndorff Spring Branch-
Trout Farm Facility

1. Main Spring (sample site)
2. Secondary Spring (sample site)
3. Mixing Box (sample site)
4. Trout Farm Outfall (sample site/flow)
5. Wet Weather Spring Stream (sample site/flow)

Of the 55 samples collected from the outfall, 17 had no detection of TSS (detection limit = 0.001 mg/L, Appendix H). All but five samples from the outfall were below 5.00 mg/L. The highest TSS sample from the outfall was 27.50 mg/L and was collected during a time (9:30 p.m.) when no known activity was occurring at the farm. Perhaps the car lights and human activity at this hour when work at the farm has normally ceased excited the fish and caused them to disturb the settled solids on the bottom of the raceways. However such thoughts are merely speculative.

The results of samples collected during four feedings ranged from 0.00 to 2.05 mg/L. While harvesting and cleaning, farm employees took care not to disturb the solids on the bottom of the raceways and sediment traps, but unavoidably some disturbance occurred. Cleaning of the settling traps took place on July 26, 2001. Samples collected at the end of the raceways showed elevated TSS values (0.47-1.98 mg/L) for the first 25 minutes after cleaning the lower most raceway but were back to 0.00 mg/L within the next 25 minutes. In general, samples collected on the following day, July 27, had higher TSS concentrations. This trend may indicate that the disturbed solids during cleaning the previous day were still suspended in the water column but is more likely due to rain, which fell the previous day and caused an increase in flow (2.5 cubic feet per second (cfs) verses 1.8 cfs for the other days). Results of headwater samples taken on July 27, 2001 were mixed: a morning sample had a TSS of 0.00 mg/L and an afternoon sample had a TSS of 0.24 mg/L. Samples taken to document a post-cleaning harvesting event had higher TSS concentrations (3.02 to 8.29 mg/L) than other samples, however the highest value (8.29 mg/L) was obtained five minutes prior to the start of the harvesting event.

Because of the TSS variability between the four different feeding activities (average 0.17 to 1.15 mg/L), the high spike during no activity, and the spike prior to the harvesting event, the advisory panel decided not to allocate the point source loads to the various activities. A TSS load of 3.7 tons per year was estimated for the point source from an average of the 55 TMDL study samples from the trout farm outfall.

6.5 POLLUTION SOURCES

Table 6.2 presents the existing average organic solids load for Orndorff Spring Branch.

Table 6.2 Existing organic solids loading in Orndorff Spring Branch

Source Category	Organic Load (pounds per year)	Percent of Total Load
Headwaters (Spring)	13	0.3 %
Point Source (Trout Farm)	4,438	99.6 %
Nonpoint Source		
Mixed Forest	2	0.0 %
Deciduous Forest	2	0.0 %
Driveway	0	0.0 %
Hayfield	0	0.0 %
Total Existing Load	4,455	100 %

6.5.1 Natural Background Load

One water sample taken from the main and secondary springs and seven samples from the mixing area of the trout farm headwaters had a mean concentration of 0.06 mg/L of TSS. Five of the samples were under the detection limit for TSS (0.001 mg/L), and two samples had detectable TSS concentrations (0.34 mg/L and 0.24 mg/L). As mentioned earlier, one of the samples was collected after rain the previous day. The estimated spring flow of 2.08 cfs gave an estimated total solids load from the spring of 0.1 tons per year. Using an estimated 5 percent organic matter content in the solids from the spring gave an organic solids load of 13 pounds per year.

6.5.2 Point Source Load

A single point source was documented in the Orndorff Spring Branch watershed. This source is an aquaculture facility that raises trout for stocking and allows paying patrons to fish in a catch-out pond. The trout farm holds a general permit (Virginia Pollutant Discharge Elimination System Permit VAG131000) that requires quarterly monitoring of discharge flow, total suspended solids, and settleable solids. According to the general permit, the facility should monitor the effluent once every three months for the following parameters:

1) Estimate flow (million gallons per day, MGD) at the time of the sampling. There is no effluent limit for flow.
2) Report monthly average and daily maximum total suspended solids (TSS) from a composite sample, i.e., hourly grab samples, not to exceed eight grab samples, taken for the duration of an operating day, during periods of representative discharges including

fish harvesting and/or unit cleaning or solids removal operations, and combined to form one representative sample. The monthly average must not exceed 10 mg/L, and the daily maximum must not exceed 15 mg/L.

3) Report average and daily maximum settleable solids from a composite sample, i.e., hourly grab samples, not to exceed eight grab samples, taken for the duration of an operating day, during periods of representative discharges including fish harvesting and/or unit cleaning or solids removal operations, and combined to form one representative sample. The monthly average must not exceed 0.1 mL/L, and the daily maximum must not exceed 3.3 mL/L (DEQ 1998a).

A TSS load of 30.7 tons per year would be expected if the facility continuously discharged its daily maximum allowed TSS concentration. A solids load of 3.7 tons per year was estimated for the point source as determined from the monitoring during the TMDL study. The TSS load was converted to organic solid load by multiplying the TSS load by the estimated volatile solids fraction, 60 percent. The calculated organic solids load, therefore, is 4,438 pounds per year.

6.5.3 Nonpoint Source Loads

Sediment loads for the nonpoint sources in the affected stream riparian zone were estimated using the Revised Universal Soil Loss Equation (RUSLE) and a sediment delivery ratio of 0.9. The riparian zone was defined as a 300-foot land strip on each side of the stream segment. The RUSLE takes into account the vegetative cover, best management practices, slope, soil erodibility, and amount and intensity of rainfall. These factors are each assigned a numeric value, and the product of these values is multiplied by the riparian land acreage to determine an annual sediment load. Additional information about the RUSLE factors and an example calculation for Ingleside Spring Branch can be found in Appendix I.

The estimated nonpoint source (NPS) sediment load was converted to the organic solid load by multiplying the NPS sediment load by the percent organic matter content of soil. Five percent organic matter content was used to account for the labile organic matter content originating from the nonpoint sources. Land use, sediment yield, and organic solids load within the 600-foot riparian zone (2.4 acres) for Orndorff Spring Branch are described in Table 6.3.

Table 6.3 Land use, area, sediment yield, and organic solids load for the riparian area of Orndorff Spring Branch.

Land Use	Percent of Area	Sediment Yield (tons/year)	Organic Solids Load (pounds/year)
Mixed Forest	45 %	0.021	2
Deciduous Forest	51 %	0.017	2
Driveway	2 %	0.003	0
Hayfield	2 %	0.001	0
Total	**100 %**	**0.042**	**4**

6.6 TMDL CALCULATION

Virginia does not currently have water quality criteria for organic solids. For this reason, a reference watershed approach was used to identify the TMDL target loads (See Section 3.4). The reference watershed approach was modified to consider only a part of the watershed—the stream riparian zone, a 300-foot land strip on each side of the stream segment. For the TMDL calculations, Ingleside Spring Branch, the benthic reference stream, was used to set the target for the organic solids load. Owing to differences in the stream lengths between the impaired segment and the reference stream, the target load estimate was adjusted to compensate for differences between the riparian area of Orndorff Spring Branch and Ingleside Spring Branch. This adjustment was necessary because riparian size influences sediment delivery, and consequently organic solids load, to the stream.

By comparing Orndorff Spring Branch to a similar non-impaired watershed (Ingleside Spring Branch) and allowing for a 5 percent margin of safety, the amount of loading that will meet the water quality objectives is 120 pounds per year.

The TMDL established for Orndorff Spring Branch consists of a point source wasteload allocation (WLA), a nonpoint source load allocation (LA), and a margin of safety (MOS) (Table 6.4). The TMDL equation is as follows:

TMDL = WLA + LA + MOS

The WLA portion of this equation is the total loading assigned to point sources. The LA portion represents the loading assigned to nonpoint sources and includes loads from the headwaters. The MOS is the portion of loading reserved to account for any uncertainty in the data and the computational methodology used for the analysis. An explicit MOS of five percent was used in the TMDL calculation to provide an additional level of protection for aquatic life.

Table 6.4 TMDL for Orndorff Spring Branch

Watershed	Pollutant	TMDL (lbs/yr)	WLA (lbs/yr)	LA (lbs/yr)	MOS (lbs/yr)
Orndorff Spring Branch	Organic Solids	127	103	17	7

6.7 LOAD ALLOCATION

Load allocations were assigned to each source category in the watershed. Loadings from certain source categories were allocated according to their existing loads. For instance, organic solids loads from the spring and deciduous forests represent the natural condition that would be expected to exist; therefore, the loadings from these sources were not reduced. The organic solids allocation scenario for Orndorff Spring Branch is presented in Table 6.5.

Table 6.5 Organic solids load allocations for Orndorff Spring Branch

Source Category	Organic Solids Load Allocation (lbs/yr)	Percent Reduction
Headwaters (Spring)	13	0.0 %
Point Source (Trout Farm)	103	97.7 %
Nonpoint Sources		
Mixed Forest	2	0.0 %
Deciduous Forest	2	0.0 %
Driveway	0	0.0 %
Hayfield	0	0.0 %
TMDL Load (Minus MOS)	120	

6.8 LOAD REDUCTION SCENARIO

Because the loads of organic solids are either natural or very small, except for loads from the trout facility, all reductions in the scenario come from the trout facility. The goal is to reduce the organic solids load from the trout facility to 103 pounds per year.

Some Best Management Practices (BMPs), such as the use of high energy feed (42% protein and 16% fat content), are being used at the trout facility on Orndorff Spring Branch. These implemented BMPs should be continued. Additional BMPs are needed to meet the TMDL target of 97.7 percent reduction in organic solids loads (103 pounds per year). General suggestions follow, but site-specific implementations plans should be developed for this trout facility.

A summary of the TMDL implementation strategy and recommended BMPs are described in Section 13.2. The developed implementation plan should consider all BMPs and utilize the combination that works best for the farm given the known flow characteristics, available space (land), number of farm personnel, TSS concentrations, etc.

The combined use of the suggested BMPs: 1) redesigned sediment traps, 2) installation of an end-of-raceway settling basin, 3) frequent cleaning of sediment traps and the settling basin, 4) proper land application, and 5) a constructed wetland would be expected to reduce the existing organic solids effluent load (4,438 pounds per year) by 98.4 percent and allow only 71 pounds per year of organic solids from the trout farm to enter the stream. The TMDL goal is to reduce the existing load to 103 pounds per year of organic solids, a 97.7 percent reduction. Therefore, the combined use of the proposed BMPs is expected to meet the TMDL goal. A description of the proposed BMPs follows.

Sediment Traps:

Sediment traps (quiescent zones) are currently in use below raceways at the facility but should be redesigned for higher efficiency (e.g., using designs outlined in *Idaho Waste Management Guidelines for Aquaculture Operations* (IDEQ 1998)). In a study by Boardman et al. (1998), a trout farm raceway with a sediment trap had a detention time of 24 seconds, an inadequate time for most solids in the effluent to settle. They found that sediment traps are inefficient because of 1) insufficient surface area, 2) small detention time, and 3) infrequent cleanings. Redesigning the trap should increase the efficiency and result in more solids removal. Experiments of redesigned sediment traps could be incorporated into the TMDL implementation plan. Cleaning of each sediment trap at the end of the raceway every 14 days is recommended as an initial approach and should be altered according to production changes within the facility (increased cleaning frequency with increases in feed amounts) and results of follow-up monitoring. An estimated 20 percent reduction in solids loading could occur with more frequent cleanings and the use of better-designed traps (Experiments are needed to test this reduction estimation).

Settling Basin:

A sufficiently sized settling basin installed below the last raceway should increase the efficiency of TSS and organic solids removal. It could be designed to allow the effluent to be directed into a diversion channel when cleaning the settling basin. Boardman et al. (1998) found that sediment basins with 10-minute detention times are able to significantly reduce spike loadings but cannot reduce TSS concentrations during average flow conditions. Reductions during normal conditions require 20-minute detention times. Twenty-minute detention times resulted in 96 percent removal of TSS, and 30-minute detention times reduced TSS concentrations by almost 98 percent. Designing the settling basin to aim for efficiencies observed with the twenty-minute detention time in the pilot plant study is recommended.

The use of baffles in the settling basin that are spaced appropriately (to prevent scouring yet promote plug flow) is suggested as an economical way to increase flow length within the confines of a relatively small space so that solids may settle. Like the sediment traps, the efficiency of the settling basin will depend on how clean it is kept. Effluent during the cleaning of a settling basin in this TMDL study (at another facility) had a TSS concentration of 53 mg/L when the basin was full (12 inches deep with solids) and a TSS concentration of 8 mg/L when the basin had only 0.5 inches of solids.

Off-line Settling Basins/Land Application:

Solids removed from sediment traps and settling basins must not be allowed to enter the impaired stream or tributaries to the impaired stream. These concentrated slurries should be treated in off-line settling basins or be land applied in such a way that runoff will not wash the solids to nearby streams. Land application is currently used at this site. Land application practices should be reviewed to make certain the collected solids are prevented from entering the impaired stream or its tributaries in runoff from the applied field.

Constructed Wetlands:

Constructed wetlands are a possible BMP to consider at this farm. Wetlands have low capital and operating costs and provide good solids removal. The effectiveness of solids removal is variable with wetlands, but a fifty percent reduction could be expected. One drawback of constructed wetlands is the space required, but that may not be an issue at this facility. It may be possible to convert some of the impaired stream into a constructed wetland. This BMP option, like all others suggested in this report, should be reviewed by the stakeholders, including DEQ, during the implementation-planning phase.

7 PHEASANTY RUN TMDL

7.1 INTRODUCTION

In 1996, part of Pheasanty Run in the James River Basin was declared impaired for failing to support aquatic. The impaired segment begins at a fish cultural station discharge and continues downstream for 0.43 miles (about 2,270 feet) to the confluence with the Cowpasture River. The effluent from the trout facility was suspected as the cause of the impairment, but the exact pollutant or pollution causing the impairment was not identified. The stream received a priority of "medium" for not/partially supporting the aquatic life use (DEQ 1998b).

7.1.1 Watershed Background

Pheasanty Run originates in a forested area of Bath County, Virginia. It is joined by spring waters from Coursey Springs. Coursey Springs is one of the largest springs in Virginia, producing 9-10 million gallons per day of water. Most, or sometimes all, of the spring water flows through raceways where fish are reared. The water exits the trout facility and enters the small stream known as Pheasanty Run. Excess water from the spring and stormwater runoff from adjacent fields is diverted to a side channel (Spring Run) that also discharges into Pheasanty Run.

The impaired stream is known locally as Spring Run. For the purposes of this TMDL report, the stream names used in the DEQ permit documents will be used: the impaired stream is called Pheasanty Run; Spring Run refers to the side stream that enters into the impaired stream.

The Pheasanty Run watershed is part of the James River hydrologic unit number 02080201 with watershed identification code of VAV-I14R. Pheasanty Run discharges into the Cowpasture River. Waters from the James River Basin eventually flow to the Chesapeake Bay. The watershed drainage area is in the Central Appalachian Ridge and Valley ecoregion.

The benthic macroinvertebrate surveys of the impaired segment of Pheasanty Run were compared to surveys taken from a reference stream to obtain the impaired status. The reference stream is a part of Mount Solon Spring Branch. The reference stream is located in Augusta County, Virginia. Like the impaired stream, the reference stream is in the Central Appalachian Ridge and Valley ecoregion, limestone sub-region.

Watershed delineation for both the impaired stream segment and the reference stream followed natural topographic drainage divides (Appendix E). The watershed area for Pheasanty Run is about 1,320 acres, while the watershed area for the reference stream, Mount Solon Spring Branch, is approximately 220 acres.

The land use of the Pheasanty Run watershed is primarily deciduous forest (64%) and pastureland (33%). Commercial/service, residential, and the trout rearing facility comprise the remaining 3% of the land use. Route 678 is the main road that transects the watershed.

The land use for the watershed of Mount Solon Spring Branch is residential (52%), pastureland (46%), and deciduous forests (2%). Water runoff from Routes 731 and 747, as they transect the watershed, drains to Mount Solon Spring Branch.

7.2 BENTHIC MONITORING

7.2.1 DEQ Benthic Monitoring

DEQ's biological monitoring on June 5, 1995 (using Rapid Bioassessment Protocol (RBP) II) indicated severe benthic impairment on Pheasanty Run compared to the reference stream, Mount Solon Spring Branch.

The monitored station on Pheasanty Run was established approximately 330 feet downstream of the trout farm discharge. Only eight macroinvertebrate taxa of relatively pollution tolerant organisms were observed in Pheasanty Run. There were no scrappers or shredders, indicating an ecological imbalance in the types of organisms found. There were also no Ephemeroptera, Plecoptera, or Tricoptera (EPT) in the sample, which are considered to be indicators of good water quality. Approximately 57% of the organisms came from a single family, the Asellidae (sow bugs). The Asellidae are scavengers, and a high density of scavengers is common in enriched waters (Bolgiano 1995c). Although a survey was not conducted on Pheasanty Run upstream of the fish cultural station discharge, an inspection of the substrate on June 5, 1995 revealed the presence of organisms from families not present at the Pheasanty Run site below the discharge. Additional macroinvertebrate sampling in August 2000, revealed similar results. Only four families of relatively pollution tolerant organisms were represented in the impaired segment, and the Asellidae dominated the sample (Van Wart 2000c).

On June 5, 1995, DEQ also monitored two stations on the Cowpasture River. One station was situated upstream of the confluence with Pheasanty Run, and the other was located 0.33 miles downstream of the confluence with Pheasanty Run. The Cowpasture River sites were determined to be non-impaired (Bolgiano 1995c).

7.2.2 TMDL Benthic Monitoring

As a part of the TMDL study, it was recommended that a more in-depth benthic study be conducted to provide additional data for further evaluation of the impaired status of the streams. See Appendix A for more information.

Mount Solon Spring Branch (Reference Stream):

The benthic community at Mount Solon Spring Branch was composed of 19 taxa occurring in the samples. Only three of the taxa were Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (stoneflies) (EPT) taxa. Isopods were the most common taxon, but overall no single or even a few taxa dominated the community in terms of abundance. Four taxa of snails were found; the two taxa of pleurocerid snails were fairly common whereas the other two taxa occurred only in one sample each. The abundance of isopods made the relative abundance of shredders the highest of the functional feeding groups. The HBI value of 7.3 reflected a community composed of "moderately tolerant" to "tolerant" taxa.

Pheasanty Run:

The benthic community at Pheasanty Run was significantly different from its reference site (Mount Solon Spring Branch) in four of the seven metrics. This was the only site (of the six impaired sites in this report) where the density of organisms was significantly different, being about four times greater than at the reference site. Only one EPT taxon occurred in the samples, and the percent EPT taxa was significantly different from the reference site. The community was dominated by "tolerant" taxa, especially isopods, oligochaetes and planarians, similar to previous DEQ benthic surveys. No snails were found in the samples; the lack of these scrapers led to the percent scraper metric being significantly different from the reference site. The mean HBI value for the site was 8.8, reflecting the dominance of "tolerant" taxa.

Pheasanty Run may be impaired based on the much higher density of macroinvertebrates than expected, the extent of the numerical dominance of "tolerant" taxa and the occurrence of only one EPT taxon in the samples.

7.3 VISUAL SURVEY

The objective of the visual survey was to document environmental conditions with potential to affect the benthic community. The visual survey involved observing and cataloging water and land conditions, land and water uses, and the changes that take place along defined stream segments (Appendix F).

Mount Solon Spring Branch (Reference Stream):

Mount Solon Spring is located in the town of Mount Solon. A concrete wall impounds the spring. The visual survey included the water exiting the impoundment to a length of less than 200 feet. The water going over the spillway enters a pipe and flows underground for approximately 75-100 feet. The spring water enters the stream from a concrete pipe. The effluent from a small sewage treatment facility for a building with three apartments enters the stream on the left through a four-inch plastic pipe. The left stream bank is mostly lawn, and the right side is a wetland area with some trees and a nearby building. Three trash piles were documented: residential trash in and by the water as it exits the underground pipe, a few tires on the left side near the sewage treatment discharge, and about 120 square feet of ground covered by large sheets of scrap metal by the stream and close to the road. A drainage ditch along Route 731 (Natural Chimney's Road) feeds to the stream. The lower boundary of the visual survey occurred where the stream flows through three three-foot metal corrugated pipes to pass under Route 731.

Pheasanty Run:

The visual survey included the impaired segment of Pheasanty Run from the trout facility outfall to the stream's confluence with the Cowpasture River. Four point discharges were observed entering Pheasanty Run. Each represents the effluent from one of the raceways where trout are reared. Inadequate riparian buffer zones of trees and shrubs along the stream were the most frequently documented environmental condition. A 50-foot inadequate buffer was observed on both sides of the stream near the trout farm effluent discharge. The right side of the stream is a former pasture field that has been abandoned and is currently used as wildlife habitat. Mowing of the grass along a strip by the stream allows easy access to the stream. Approximately 2,000 feet of grass growing along the stream in this field could be converted to trees to increase the riparian vegetative buffer. Three stream bank erosion sites were observed. The first was about 300 feet in length and about 3 feet in height. The second is 60 feet in length and a little more than 3 feet in height. The third is a 20-foot section by a bend at a steep slope. One pick-up truck load of scrap metal and other construction type trash was observed near the confluence with Spring Run and Pheasanty Run.

Wildlife appears abundant in Pheasanty Run. Fish, turtles, snakes, deer, and ducks were observed in the stream. Various species of birds of prey were seen and heard in the vicinity, including two bald eagles. Local bird-watchers come to the area to observe the birds attracted to the fish cultural station.

7.4 FISH SURVEY

Because Pheasanty Run is a stocked trout stream, a fish survey was conducted to determine the likely impact of fish predation on the macroinvertebrate community. Thirteen species of fish, including 133 introduced rainbow trout (*Oncorhynchus mykiss*) and 3 introduced brown trout (*Salmo trutta*) were represented in collections (Appendix C). Numerically dominant native species were the white sucker (*Catostomus commersoni*) and mottled sculpin (*Cottus bairdi*). Overall fish abundance was 9.9 fish per minute. The fish survey indicates that selective predation by relatively high densities of introduced trout in Pheasanty Run could affect the results of the benthic macroinvertebrate bioassessments; however, a more detailed study of trout feeding ecology would be necessary to test the hypothesis. Based on the fish survey findings, the advisory panel concluded that fish predation is probably a stressor but unlikely to be a critical stressor.

7.5 PHYSICAL/CHEMICAL MONITORING

7.5.1 DEQ and Other Physical/Chemical Monitoring

Discharge monitoring reports (DMR) from January 1999 through December 2001 indicate the required measured parameters (TSS, SS, BOD_5, ammonia, pH, and DO) are within the required standards. One TSS concentration was considerably lower than the other data. After removing this value, an average load of 52.0 tons per year of solids was estimated from the discharge monitoring reports.

Boardman et al. (1998) obtained inlet, within farm, and outlet water quality data for three trout farms in Virginia from September 1997 to April 1998 on a bi-monthly basis. Their TSS findings are shown in Table 7.1. Using the average TSS concentrations from the farm effluents with the lowest and highest TSS concentrations (Farm A, 3.0 mg/L; Farm C, 5.8 mg/L) and a spring flow of 15.99 cfs (comparable to the spring flow in this study), a TSS load of 47.3 tons per year to 91.4 tons per year could be expected.

Table 7.1 Total suspended solids concentrations for trout farms A, B, and C. "Within Farm" refers to data obtained from the end of all active raceways in each farm.

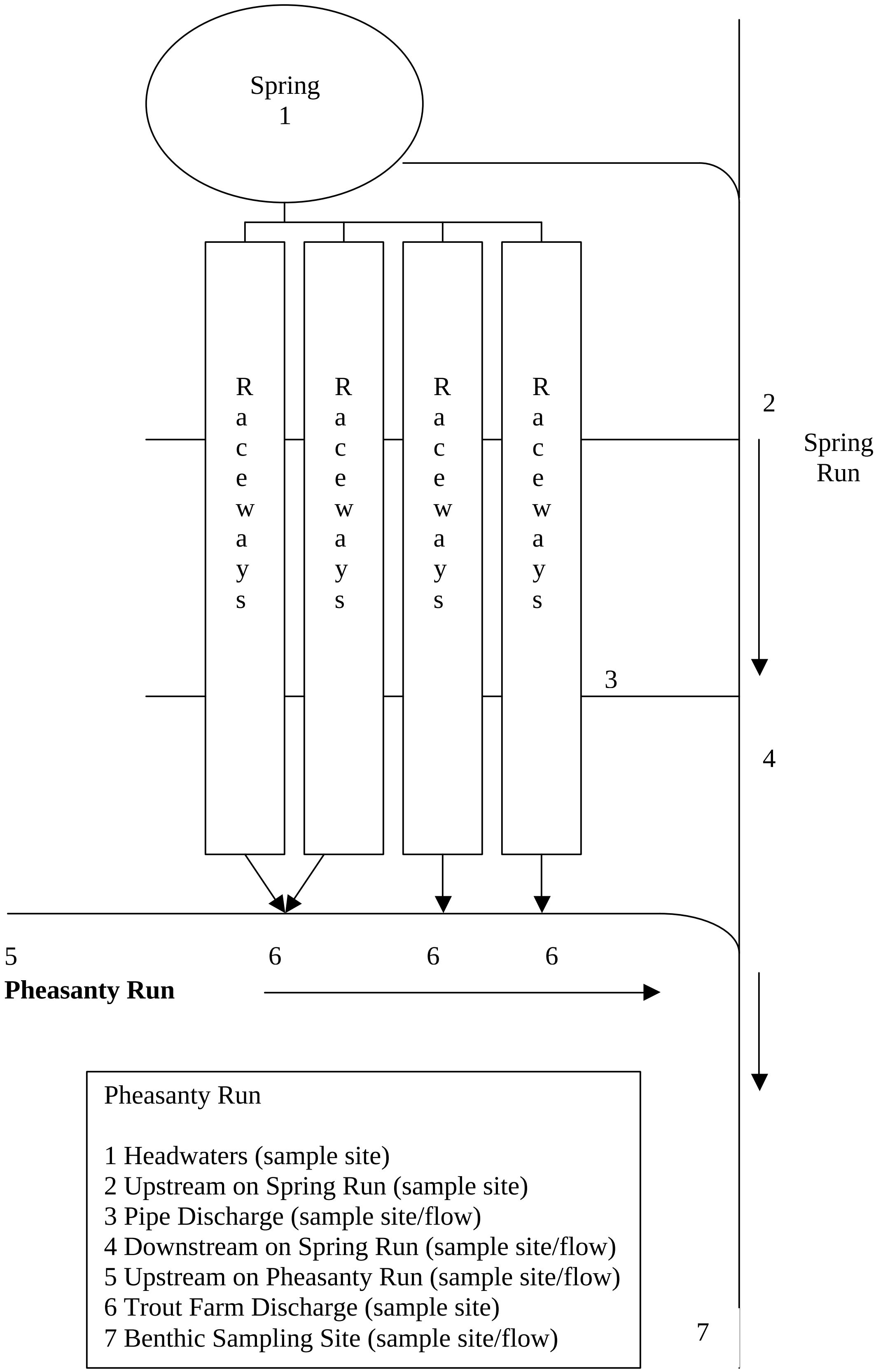
	Farm A			Farm B			Farm C		
(mg/L)	Inlet	Within Farm	Outlet	Inlet	Within Farm	Outlet	Inlet	Within Farm	Outlet
TSS range	0-1.1	0-30.4	0.8-6.0	0-1.8	0-43.7	1.5-7.5	0-1.5	0-28	4.1-62
TSS average	0.2	3.9	3.2	0.5	5.3	3.9	0.3	7.1	6.1*

*Two outliers removed for calculation of the average

7.5.2 TMDL Physical/Chemical Monitoring

Sampling at the trout facility for the TMDL study occurred between August 1, 2001 and January 31, 2002. Samples were collected from Pheasanty Run upstream of the trout facility outfalls, within the spring, in the upstream portion of Spring Run (the side stream), a pipe discharge to Spring Run, at the lower portion of Spring Run, from the outfalls of the trout facility, at the benthic sampling location, and near the end of the impairment (Figure 7.1). The samples taken

Figure 7.1 Diagram of sample collection sites and stream flow measurement sites for the trout farm facility on Pheasanty Run. Not drawn to scale.



Pheasanty Run

1 Headwaters (sample site)
2 Upstream on Spring Run (sample site)
3 Pipe Discharge (sample site/flow)
4 Downstream on Spring Run (sample site/flow)
5 Upstream on Pheasanty Run (sample site/flow)
6 Trout Farm Discharge (sample site)
7 Benthic Sampling Site (sample site/flow)

upstream of the trout farm on Pheasanty Run consistently had the highest TSS concentrations (6.75 to 35.11 mg/L) and the lowest flows (average 0.37 cfs) (Appendix H).

The side stream, Spring Run, is influenced by spring waters, runoff, and effluent from the trout facility. It receives water directly from the spring, which has bypassed the trout facility. Low flows hampered water collection for the upper part of this side stream. Two samples collected had TSS concentrations of 0.00 mg/L and 2.44 mg/L (TSS detection limit = 0.001 mg/L). A pipe discharge, which funnels runoff flows and raceway water to the side stream, had average TSS concentrations of 3.20 mg/L (range 2.70 to 3.60 mg/L). The downstream sampling site on Spring Run, below the pipe discharge, had an average TSS concentration of 3.73 mg/L (range 1.84 to 7.62 mg/L).

Five samples collected directly from the trout outfalls had an average concentration of 3.84 mg/L (range: 0.46-9.49 mg/L). Multiplying this concentration by the average measured flow (15.99 cfs), gave a TSS load of 60.4 tons per year.

7.6 POLLUTION SOURCES

Table 7.2 presents the existing average annual organic solids load for Pheasanty Run.

Table 7.2 Existing organic solids loading in Pheasanty Run

Source Category	Organic Load (pounds per year)	Percent of Total Load
Headwaters (Spring)	0	0.0 %
Point Source (Trout Farm)	72,477	99.4 %
Nonpoint Source Upstream Section		
Grassy Field	138	0.2 %
Road/Driveway	124	0.2 %
Deciduous Forest	26	0.0 %
Impaired Section		
Grassy Field	143	0.2 %
Deciduous Forest	6	0.0 %
Total Existing Load	**72,914**	**100%**

7.6.1 Natural Background Loads

Samples taken from the headwaters of Pheasanty Run (Coursey Springs) on four occasions during the TMDL study had TSS concentrations below the detection limit (0.001 mg/L).

Therefore, based on the data from the TMDL study, no organic solids load was attributed to the headwaters.

7.6.2 Point Source Loads

A single point source was documented in the Pheasanty Run watershed, a state-owned aquaculture facility operated by the Virginia Department of Game and Inland Fisheries (DGIF). It is the largest trout rearing station managed by the state. Brook, brown, and rainbow trout fry are grown to fingerlings (less than legal size) and adult trout. The fish are stocked in public accessible trout streams west of the Blue Ridge from Alleghany County north (DGIF 2001).

The fish cultural station holds Virginia Pollutant Discharge Elimination System (VPDES) Permit Number VA006491, an individual permit, for the discharge of wastewater to Pheasanty Run. According to a 1997 memo from DEQ personnel concerning the re-issuance of the VPDES permit, "The application and draft permit have received public notice in accordance with the Permit Regulation, and no comments were received…. The discharge is not controversial and is currently meeting the required effluent limitations" (DEQ 1997a).

Individual permits generally require monthly monitoring, but quarterly monitoring is required for this facility because it has a 20-year record of compliance. The discharge flow is estimated on a quarterly basis at the time of discharge sampling. The effluent is sampled and analyzed for total suspended solids (TSS), settleable solids (SS), biochemical oxygen demand (BOD_5), ammonia, pH, dissolved oxygen (DO), and total residual chlorine (TRC). The monitoring requirements for nitrogen and phosphorus have been removed from the permit because they only apply to nutrient-enriched State Waters, and the receiving stream is not designated as nutrient-enriched.

DGIF personnel are required to sample during periods of representative discharges and during discharges associated with fish harvest and/or solids removal. The pH, dissolved oxygen, and TRC parameters are analyzed from grab samples. The TSS, SS, BOD_5, and ammonia parameters are analyzed from composites of five grab samples collected during an eight-hour period. The discharge permit requirements are as follows (DEQ 1997b):

- Estimate flow (million gallons per day, MGD) at the time of the sampling. There is no effluent limit for flow.
- The monthly average TSS concentration must not exceed 10 mg/L, and the maximum daily TSS concentration must not exceed 15 mg/L.
- The monthly average SS concentration must not exceed 0.1 mL/L, and the daily maximum SS concentration must not exceed 0.5 mL/L.
- The monthly average BOD_5 must not exceed 10 mg/L.
- The daily maximum limit for ammonia is 1.8 mg/L.
- The pH for the discharge must be maintained between 6 and 9.
- The discharge DO must be greater than or equal to 6.6 mg/L.

DGIF personnel reported the occasional use of Chloramine-T in the past to control diseases, such as Bacterial Gill Disease and Columaris Disease. Because the use of Chloramine-T is infrequent and the duration of its use is generally less than two hours, the halogen ban section (9 VAC 25-260-110) does not apply to this facility. When Chloramine-T is in use, the facility is to operate decholorination equipment when the dosing begins and continue until the treated water has been flushed from the system, and the effluent is to be monitored for TRC (DEQ 1997b). According to facility personnel, Chloramine-T is no longer used.

A TSS load of 236.3 tons per year would be expected if the facility continuously discharged its daily maximum allowed TSS concentration. A solids load of 60.4 tons per year was estimated for the point source as determined from the monitoring during the TMDL study. The TSS load was converted to organic solids load by multiplying the TSS load by the estimated volatile solids fraction obtained from solids collected from the bottom of settling basins from three of the studied trout farms, 60 percent. The calculated organic solids load, therefore, is 72,477 pounds per year.

7.6.3 Nonpoint Source Loads

Nonpoint source contributions were estimated for the impaired stream segment and upstream of the impaired segment for an effective stream stretch of 2,000 feet (1,700 feet upstream of the impaired section's riparian buffer area), approximately the same length as the impaired segment. Sediment loads for the nonpoint sources were estimated using the Revised Universal Soil Loss Equation (RUSLE) in the riparian area and a sediment delivery ratio of 0.9. The riparian zone was defined as a 300-foot land strip on each side of the stream segment.

The RUSLE takes into account the vegetative cover, best management practices, slope, soil erodibility, and the amount and intensity of rainfall. These factors are each assigned a numeric value, and the product of these values is multiplied by the riparian land acreage to determine an annual sediment load. Additional information about the RUSLE factors and an example calculation for Ingleside Spring Branch, the organic solids load reference, can be found in Appendix I.

The estimated nonpoint source (NPS) sediment load was converted to the organic solid load by multiplying the NPS sediment load by the percent organic matter content of soil. Five percent organic matter content was used to account for the labile organic matter content originating from the nonpoint sources. Land use, sediment yield, and organic load within the 600-foot riparian zone of the upstream section of Pheasanty Run (23.4 acres) and for the impaired section of Pheasanty Run (29.9 acres) described in Table 7.3.

Table 7.3 Land use, area, sediment yield, and organic solids load for the riparian area of the upstream and impaired sections of Pheasanty Run.

Land Use	Percent of Area	Sediment Yield (tons/year)	Organic Solids Load (pounds/year)
Upstream Section			
Grassy Field	93 %	1.4	138
Road/Driveway	2 %	1.2	124
Deciduous Forest	5 %	0.3	26
Total	**100 %**	**2.9**	**288**
Impaired Section			
Grassy Field	91 %	1.4	143
Deciduous Forest	9 %	0.1	6
Total	**100 %**	**1.5**	**149**

7.7 TMDL CALCULATION

Virginia does not currently have water quality criteria for organic solids. For this reason, a reference watershed approach was used to identify the TMDL target loads (See Section 3.4). The reference watershed approach was modified to consider only a part of the watershed—the stream riparian zone, a 300-foot land strip on each side of the stream segment.

For the TMDL calculations, Ingleside Spring Branch was used to set the target for the organic solids load. Ingleside Spring Branch was selected as the reference because it is a non-impaired, spring-fed stream in the Central Appalachian Ridge and Valley ecoregion, limestone sub-region. Mount Solon Spring Branch, the benthic reference stream, was not used to set the target because the point source contributions of this stream were not determined, and the target based only on the nonpoint sources yields a very difficult goal to attain. Additionally, Ingleside Spring Branch had more macroinvertebrate taxa, a higher density of organisms, and a lower mean HBI value compared to Mount Solon Spring Branch, indicating that Ingleside Spring Branch is a slightly higher quality stream in terms of the benthic macroinvertebrate community (Appendix A).

Owing to differences in the stream lengths between the impaired segment and the organic solids reference stream, the target load estimate was adjusted to compensate for differences between the riparian area of Pheasanty Run and Ingleside Spring Branch. This adjustment was necessary because riparian size influences sediment delivery, and consequently organic solids load, to the stream.

By comparing Pheasanty Run to a similar non-impaired watershed (Ingleside Spring Branch) and allowing for a 5 percent margin of safety, the amount of organic solids loading that will meet the water quality objectives is 1,502 pounds per year. When this value is met, Pheasanty Run is expected to meet its aquatic life use.

The TMDL established for Pheasanty Run consists of a point source wasteload allocation (WLA), a nonpoint source load allocation (LA), and a margin of safety (MOS) (Table 7.4). The TMDL equation is as follows:

TMDL = WLA + LA + MOS

The WLA portion of this equation is the total loading assigned to point sources. The LA portion represents the loading assigned to nonpoint sources. The MOS is the portion of loading reserved to account for any uncertainty in the data and the computational methodology used for the analysis. An explicit MOS of five percent was used in the TMDL calculations to provide an additional level of protection for aquatic life.

Table 7.4 TMDL for Pheasanty Run

Watershed	Pollutant	TMDL (pounds/yr)	WLA (pounds/yr)	LA (pounds/yr)	MOS (pounds/yr)
Pheasanty Run	Organic Solids	1,582	1,231	271	80

7.8 LOAD ALLOCATION

Load allocations were assigned to each source category in the watershed based on information from the visual survey, knowledge of best management practices, and professional judgment. Loadings from certain source categories were allocated according to their existing loads. For instance, an organic solids load from the deciduous forest represents the natural condition that would be expected to exist; therefore, the loadings from this source were not reduced. The organic solids allocation scenario for Pheasanty Run is presented in Table 7.5.

Table 7.5 Organic solids load allocations for Pheasanty Run

Source Category	Organic Solids Load Allocation (lbs/yr)	Percent Reduction
Headwaters (Spring)	0	0 %
Point Source (Trout Farm)	1,231	98 %
Nonpoint Sources		
Upstream Section		
Grassy Field	55	60 %
Road/Driveway	124	0 %
Deciduous Forest	26	0 %
Impaired Section		
Grassy Field	60	58 %
Deciduous Forest	6	0 %
TMDL Load (Minus MOS)	1,502	

7.9 LOAD REDUCTION SCENARIO

The Best Management Practices (BMPs) described below should be sufficient to reduce the needed organic solids load to the TMDL target. The developed implementation plan should consider all BMPs and utilize the combination that works best for this impaired stream section. A summary of the TMDL implementation strategy and recommended BMPs are described in Section 13.2.

7.9.1 Point Source Reduction Scenario

The state had a Facility Improvements and Options plan developed for the trout facility located on Pheasanty Run. The report recommends that the existing earthen raceways be replaced with a concrete raceway bank or adding precast concrete walls and floors to the existing raceways. Each raceway is to be equipped with an individual settling basin. The report also recommends allowing space for a settling clarifier and an aerobic effluent treatment pond. A sludge handling and removal system is also suggested. This plan should be utilized in the decision making process of the implementation plan.

Best Management Practices (BMPs) should be incorporated into any newly designed system. The facility is already using some BMPs, such as the use of high energy feed (42-55% protein and 12-15% fat content). These implemented BMPs should be continued. Additional BMPs are needed to meet the TMDL target of 98 percent reduction in organic solids loads (1,231 pounds per year). General suggestions follow, but site-specific implementations plans should be developed for this trout facility.

The combined use of the suggested BMPs: 1) redesigned sediment traps, 2) installation of an end-of-raceway settling basins, 3) frequent cleaning of sediment traps and the settling basin, and 4) proper land application would be expected to reduce the existing organic solids effluent load (72,477 pounds per year) by 98.4 percent and allow 1,160 pounds per year of organic solids from the trout farm to enter the stream. The TMDL goal is to reduce the existing load to 1,231 pounds per year of organic solids, a 98.3 percent reduction. Therefore, the combined use of the proposed BMPs is expected to meet the TMDL goal. A description of the proposed BMPs follows.

Sediment Traps:

Sediment traps (quiescent zones) are currently in use below raceways at the facility but should be redesigned for higher efficiency (e.g., using designs outlined in *Idaho Waste Management Guidelines for Aquaculture Operations*). In a study by Boardman et al. (1998), a trout farm raceway with a sediment trap had a detention time of 24 seconds, an inadequate time for most solids in the effluent to settle. They found that sediment traps are inefficient because of 1) insufficient surface area, 2) small detention time, and 3) infrequent cleanings. Redesigning the trap should increase the efficiency and result in more solids removal. Experiments of redesigned sediment traps could be incorporated into the TMDL implementation plan. Cleaning of each sediment trap at the end of the raceway every 14 days is recommended as an initial approach and should be altered according to production changes within the facility (increased cleaning frequency with increases in feed amounts) and results of follow-up monitoring. An estimated 20 percent reduction in solids loading could occur with more frequent cleanings and the use of more effective traps (Experiments are needed to test this reduction estimation).

Settling Basin:

Installation of a properly designed settling basin clarifier located below the last raceways should increase the efficiency in TSS and organic solids removal. It may also be redesigned to direct the effluent into a diversion channel when cleaning the settling basin. Boardman et al. (1998) found that sediment basins with 10-minute detention times are able to significantly reduce spike loadings but cannot reduce TSS concentrations during average flow conditions. Reductions during normal conditions require 20-minute detention times. Twenty-minute detention times resulted in 96 percent removal of TSS, and 30-minute detention times reduced TSS concentrations by almost 98 percent. Designing the settling basin to aim for efficiencies observed with the thirty-minute detention time in the pilot plant study is recommended to meet the TMDL target, unless other practices are used in conjunction with the proposed BMPs to reduce the total load from the facility.

The use of baffles in the settling basin that are spaced appropriately (to prevent scouring yet promote plug flow) is suggested as an economical way to increase flow length within the confines of a relatively small space so that solids may settle. Like the sediment traps, the efficiency of the settling basin will depend on how clean it is kept. Effluent during the cleaning of a settling basin in this TMDL study (at another facility) had a TSS concentration of 53 mg/L when the basin was full (12 inches deep with solids) and a TSS concentration of 8 mg/L when the basin had only 0.5 inches of solids.

Off-line Settling Basins/Land Application:

Solids removed from sediment traps and settling basins must not be allowed to enter the impaired stream or tributaries to the impaired stream. These concentrated slurries should be treated in off-line settling basins or be land applied in such a way that runoff will not wash the solids to nearby streams. Land application is currently used at this site. Land application practices should be reviewed to make certain the collected solids are prevented from entering the impaired stream or its tributaries in runoff from the applied field.

7.9.2 Nonpoint Source Reduction Scenario

Visual assessment indicated that the nonpoint source (NPS) sediment load, and consequently the NPS organic solids load, to Pheasanty Run originate from two different areas: a field upstream of the impaired section and an abandoned pasture along the impaired section. The upstream section flows mostly through grassland that provides inadequate buffer. Two problem areas were identified in the visual survey along the impaired section. The first problem area is an approximately 2,000-foot segment with inadequate buffer on the right side of the impaired stream. The second problem area is inadequate buffer located along a 50-foot segment on both side of the impaired stream.

The existing NPS load from the grassy field along the upstream section (138 pounds) should to be reduced to 55 pounds per year (60 percent reduction). Likewise, the required reduction of the existing NPS organic solids load from the grassy field along the impaired section (143 pounds) should be reduced to 60 pounds per year (58 percent reduction). To achieve the NPS required reduction of the organic solids load, the following Best Management Practices (BMPs) are proposed.

A filter strip of grass and canopy should be installed along the sections with inadequate canopy cover. The BMPs should improve the land cover condition, decrease runoff velocity, increase infiltration into the soil, and trap sediment before it enters the stream. Literature supports the positive effects of buffer strips on preventing sediment transport to streams (Dillaha et al. 1986) and positive impacts of cover condition on Sediment Delivery Ratio (SDR) (Novotny and Olem 1994).

BMP for Upstream Segment:

A BMP that consists of 150-foot buffer grass strip with canopy installed along each side of a 1,700-foot stream section will use 11.7 acres of the upstream riparian area (21.7 acres). The BMP installation reduces the Management Practice (P) value in the RUSLE calculation to 0.7. The C factor (0.002) is calculated as a weighted average for values in the grassy riparian area buffer strips. Other RULSE factors remain the same (K = 0.32, LS = 0.6, R = 125), and the SDR becomes 0.8. This management practice therefore will result in 0.6 tons per year sediment yield (55 pounds per year organic solids yield), which meets the percent reduction needed.

BMP for Impaired Segment:

A BMP that consists of a 300-foot buffer grass strip with canopy installed along the riparian area of a 1,950-foot section (on the right side) of the impaired stream will use 13.4 acres of the abandoned pasture in the riparian area (27.1 acres). The BMP installation is expected to reduce the Management Practice (P) value in the RUSLE calculation to 0.7. The C factor (0.002) is calculated as a weighted average for the values in the abandoned pasture and buffer strip. Other RULSE factors remain the same (K = 0.39, LS = 0.4, R = 125), and the SDR becomes 0.8. The management practice will result in 0.6 tons per year sediment yield (59 pounds per year organic solids yield), which meets the percent reduction needed.

8 WALLACE MILL SRTREAM TMDL

8.1 INTRODUCTION

A survey of benthic macroinvertebrates in June of 1996 indicated severely impaired waters at river mile 0.64 of Wallace Mill Stream (referred to as Casta Line Spring Branch in DEQ reports) and moderate impairment at river mile 0.04 (DEQ 1998b). The impaired segment begins at the outfall of a trout facility (river mile 0.80) and continues downstream to the confluence with Byrd Spring Branch (river mile 0.00). The effluent from a trout facility was suspected as the cause of the impairment, but the exact pollutant or pollution causing the impairment was not identified. The stream was initially listed in 1998 and received a priority of "medium" for not/partially supporting the aquatic life use.

8.1.1 Watershed Background

The impaired stream, known locally (and throughout this report as requested by stakeholders) as Wallace Mill Stream, is a first-order stream with a perennial spring as the headwaters. Wallace Mill Stream discharges into Byrd Spring Branch, which immediately (< 100 feet) discharges into the Little Calfpasture River. The Little Calfpasture River drains to the James River Basin, which eventually flows into the Chesapeake Bay. The Wallace Mill Stream watershed has hydrologic unit number 02080202 and watershed identification code of VAV-I32R. It is located in the Central Appalachian Ridge and Valley ecoregion in Augusta County, Virginia.

The benthic macroinvertebrate surveys of the impaired segment were compared to surveys taken from a reference stream to obtain the impaired status. The reference stream for Wallace Mill Stream is a part of Ingleside Spring Branch. The water from Ingleside Spring feeds two channels: one side flows through a trout rearing facility and the other flows through an open field. The reference stream is located in the section that flows through the open field. It is in the Central Appalachian Ridge and Valley ecoregion, limestone sub-region within Rockbridge County, Virginia.

Watershed delineation for both the impaired stream segment and the reference stream followed natural topographic drainage divides (Appendix E). The watershed area for Wallace Mill Stream is about 1,450 acres, while the watershed area for the reference stream, Ingleside Spring Branch, is approximately 50 acres.

The major land use for Wallace Mill Stream is deciduous forest (81%), located primarily in the upper drainage area of the watershed. The remaining land use is pastureland (17.5%) and residential (1.5%). Wallace Mill Stream crosses under Route 683 twice and under Routes 601 and 684 before discharging into Byrd Spring.

The land use for the watershed of Ingleside Spring Branch is pastureland (99%) and transportation (1%). Water runoff from Route 612, as it transects the watershed, drains to Ingleside Spring Branch.

8.2 BENTHIC MONITORING

8.2.1 DEQ Benthic Monitoring

Virginia DEQ's biological monitoring on May 14, 1996 (using Rapid Bioassessment Protocol (RBP) II) indicated severe benthic impairment on Wallace Mill Stream. The severely impaired site was characterized by having seven families of relatively pollution tolerant organisms. The shredder category of organisms was absent, and the sample was dominated (67%) by the Chironomidae spp. (midges). At the time of the 1996 survey, DEQ personnel described the stream as flowing "through a second growth forest with no stock animals near the stream" and observed, "a flush of very turbid gray water [that] came from upstream. A pronounced musty odor was evident" (Bolgiano 1996b).

An additional survey on May 14, 1996 on Wallace Mill Stream near the stream's confluence with Byrd Spring Creek (0.6 miles downstream of the first sampling site) showed improvement, being at the low end of moderately impaired. Twelve families were present in the sample, and the Chironomidae spp. were dominant (54%). Benthic surveys of the receiving stream, Little Calfpasture River, indicated it was unimpacted (Bolgiano 1996b).

Additional macroinvertebrate sampling by Virginia DEQ in August 2000 found only six families at the upstream benthic sampling site. In the 2000 sampling, the Asellidae dominated the sample, whereas in the 1996 sampling, the Chironomidae were dominant. In the 2000 sampling, only one Chironomidae was recovered (Van Wart 2000d). At the site just above the confluence with Byrd Spring Creek, the August 2000, sampling resulted in nine families. Once again, the Asellidae were the dominant organisms (Van Wart 2000e).

8.2.2 TMDL Benthic Monitoring

As a part of the TMDL study, it was recommended that a more in-depth benthic study be conducted to provide additional data for further evaluation of the impaired status of the streams. See Appendix A for more information.

Ingleside Spring Branch (Reference Stream):

The benthic community at Ingleside Spring Branch was composed of a variety of species, 23 taxa occurring in the five replicate samples combined and five of those being Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (stoneflies) (EPT) taxa. Scrapers dominated the community because of the abundance of the snail *Somatogyrus*, by far the most abundant taxon at the site. The mean HBI value of 6.2 reflected a community composed of primarily moderately tolerant taxa. Few taxa with HBI values indicative of highly tolerant species were common at the site, whereas a number of taxa that have low HBI values indicating intolerant species were common.

Wallace Mill Stream:

The two assessed sites on Wallace Mill Stream were quite different from each other. The site at river mile 0.64 (Wallace Mill A) was significantly different from its reference site (Ingleside Spring Branch) in all metrics but density. Only eight taxa occurred in the samples from this site, none of which was an EPT taxon. The dominant taxa were isopods, oligochaetes and planarians, reflecting poor water and habitat quality. Isopods also were the dominant taxa in the DEQ benthic surveys taken in August 2000. The mean HBI value of 7.4 reflected a community composed of "moderately tolerant" to "tolerant" taxa.

The benthic community at the downstream site on Wallace Mill Stream (B) indicated somewhat better conditions in the stream. Only two metrics, the percent scrapers and percent shredders, were significantly different from the reference site. Taxa and EPT richness were quite similar to the reference site, with four EPT taxa occurring in the samples. Although oligochaetes and isopods again were the most common taxa, they did not dominate to the extent that they did upstream. Despite the HBI value (8.7) being higher for the downstream site, the other metrics together show this site to have a higher quality than the upstream site because no one metric decides the "quality" of a site, but rather the overall suite of metrics provides the information to make the decision.

In summary, Wallace Mill Stream was impaired at the upstream site as indicated by the low species richness, total lack of EPT taxa and high relative abundance of oligochaetes and isopods. The data suggest that the stream quality was improved at the downstream sampling site, as indicated by the higher richness, the presence of EPT taxa and the presence of tolerant taxa in numbers that were not as dominant as they were upstream.

8.3 VISUAL SURVEY

The objective of the visual survey was to document environmental conditions with potential to affect the benthic community. The visual survey involved observing and cataloging water and land conditions, land and water uses, and the changes that take place along defined stream segments (Appendix F).

Ingleside Spring Branch (Reference Stream):

The visual survey of Ingleside Spring Branch encompassed approximately 500 feet of the stream. The survey began just below the spring and continued downstream (on the side not used for the trout farm) to the confluence with North Buffalo Creek. Adequate riparian vegetation (e.g., tree canopy) was lacking for the entire stream length on both banks. The land adjacent to the stream consisted of the trout farm (not the trout farm under study) on the left bank and an open field on the right bank. Livestock does not have access to the stream. One channel alteration was documented: three metal pipes to allow flow under a gravel drive that crosses the stream.

Wallace Mill Stream:

The headwaters of Wallace Mill Stream are a perennial spring in a deciduous area. The stream flows through two series of raceways for rearing trout: an upper series and a lower series. Water from the upper series of raceways flows through a wooded area. Some of this water bypasses the second set of raceways and follows an earthen channel around the facility. Most of the water goes to the second series of raceways. The effluent from the lower series of raceways enters the stream via one of two ways: a chute to the stream or through a pond and then to the stream. A second adjacent pond, formerly used for fee fishing, was dry during the survey period but also discharges into the stream.

Wallace Mill Stream leaves the wooded area and flows through pastureland, under roadways, and by a small residential area before discharging into Byrd Spring Branch. The visual survey of Wallace Mill Stream included the side stream that joins the trout farm effluent, and the impaired segment that flows 0.8 miles downstream to its confluence with Byrd Spring Branch. Access to the land of one of the property owner's was denied so approximately 0.15-0.2 miles (<1,000 feet) of the stream were not surveyed. At this location, the stream flows through a pasture field where cattle have access to the stream.

Observed environmental conditions include: inadequate vegetative buffer zones along the streambanks, livestock with access to the stream, erosion sites, drainage ditches, channel alterations, an outfall, and an exposed pipe. Approximately 0.6 miles of the 0.8 miles of the impaired segment was estimated to have an inadequate buffer zone of trees and other tall vegetation. During the survey, livestock had access to two fields through which Wallace Mill Stream flows. Livestock were observed in a third pasture field at a later date, indicating that at different times of the year livestock may have access up to 0.5 miles of the impaired segment. Three eroded hill slopes were documented. Erosion sites along the streambanks accounted for over 750 feet of the surveyed stream, and the stream segment not surveyed also had evident erosion sites. The largest streambank erosion site occurred above the upstream benthic sampling location and was approximately 150 feet in length and over 6 feet in height.

One outfall and two drainage ditches were observed in the upper reaches of the impaired segment: 1) the outfall for a trout farm, and 2) ditches leading from two abandoned fee fishing ponds. Drainage ditches along Routes 683, 601, and 684 feed into Wallace Mill Stream. These three roads cross the stream at four locations, accounting for all of the observed channel alterations. One exposed pipe was observed crossing the streambed. This pipe was believed to carry spring water to a house.

8.4 PHYSICAL/CHEMICAL MONITORING

8.4.1 DEQ and Other Physical/Chemical Monitoring

A review of the quarterly discharge monitoring reports from March 1999 to December 1999 and from April 2001 to December 2001 indicates compliance with the permit. Facility personnel also report compliance with the permit for the past five to ten years. Total suspended solids (TSS) concentrations of 2.0 to 4.0 mg/L were reported for spring flows with 1.15 to 2.17 cubic feet per second (cfs) and yielding loads of 2.3 to 8.6 tons per year. The average TSS load from the data is 4.4 tons per year.

Boardman et al. (1998) obtained inlet, within farm, and outlet water quality data for three trout farms in Virginia from September 1997 to April 1998 on a bi-monthly basis. Their TSS findings are shown in Table 8.1. Using the average TSS concentrations from the farm effluents with the lowest and highest TSS concentrations (Farm A, 3.0 mg/L; Farm C, 5.8 mg/L) and a spring flow of 1.58 cfs (comparable to the spring flow in this study), a TSS load of 4.7 tons per year to 9.0 tons per year could be expected.

Table 8.1 Total suspended solids concentrations for trout farms A, B, and C. "Within Farm" refers to data obtained from the end of all active raceways in each farm.

	Farm A			Farm B			Farm C		
(mg/L)	Inlet	Within Farm	Outlet	Inlet	Within Farm	Outlet	Inlet	Within Farm	Outlet
TSS range	0-1.1	0-30.4	0.8-6.0	0-1.8	0-43.7	1.5-7.5	0-1.5	0-28	4.1-62
TSS average	0.2	3.9	3.2	0.5	5.3	3.9	0.3	7.1	6.1*

*Two outliers removed for calculation of the average

8.4.2 TMDL Physical/Chemical Monitoring

Sampling at the trout facility for the TMDL study occurred from August 8-August 10, 2001 and on February 2, 2002. Samples were collected from the headwaters, end of the first series of raceways, beginning of second series of raceways, side stream, trout farm outfall, ditch from the uppermost fee fishing pond, and the uppermost benthic sampling location (Figure 8.1). Water

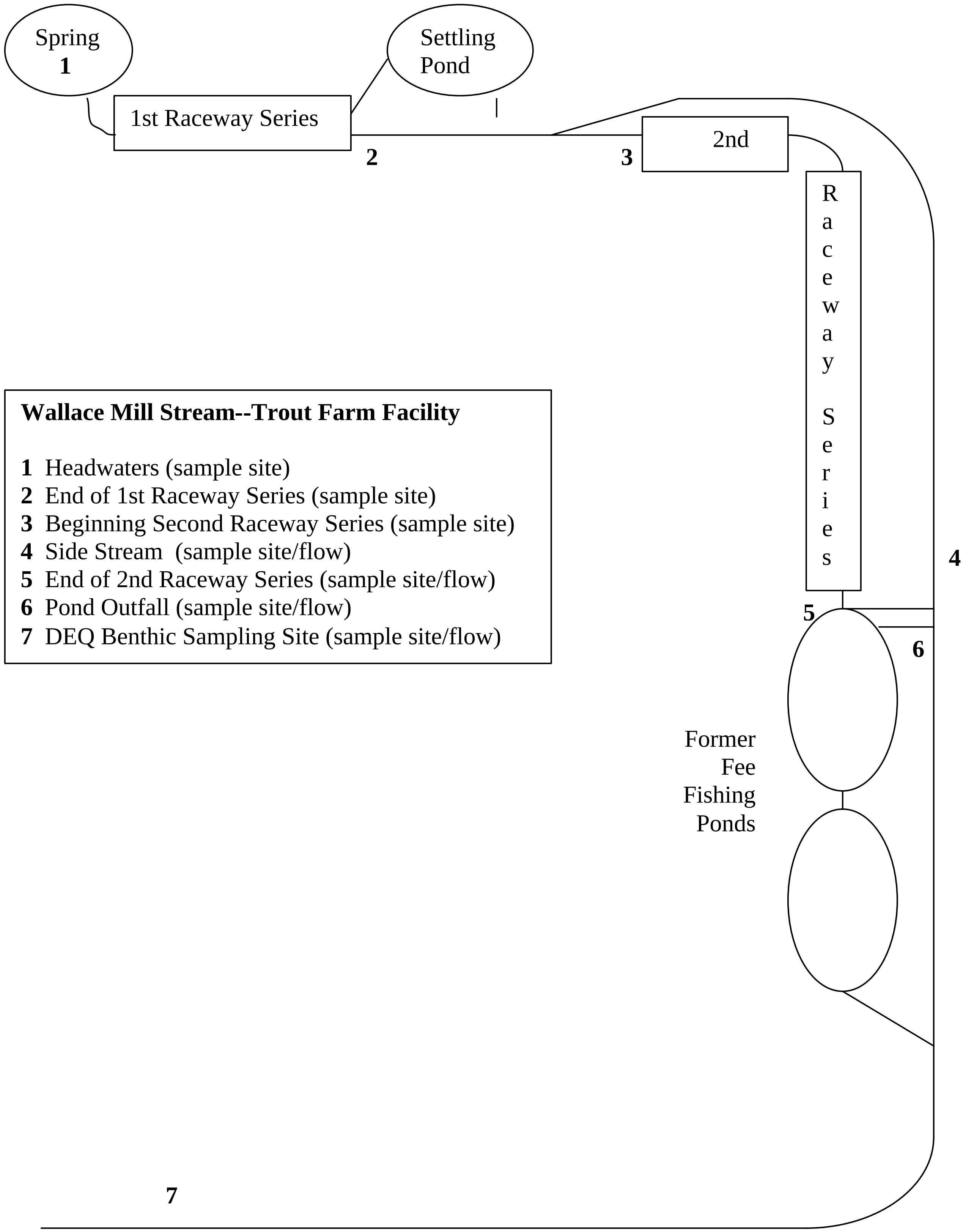


Figure 8.1. Diagram of sample collection sites and stream flow measurement sites for the trout farm facility on Wallace Mill Stream. Not drawn to scale.

samples were also collected from an entering stream located between the two benthic sampling sites and at the downstream benthic sampling site (near the end of the impairment). Samples were collected during the various activities that take place at the farm (Appendix G). The four samples from the headwaters had TSS concentrations below the detection limit (0.001 mg/L, Appendix H).

Of the 34 samples collected from the trout farm outfall, 11 had TSS concentrations under the detection limit (0.001 mg/L, Appendix H). All but three samples were below 5.00 mg/L. The highest TSS sample was 19.06 mg/L and was collected during a time when no known activity was occurring at the farm. The outfall TSS concentrations of samples collected during three feedings ranged from 0.00 mg/L to 6.74 mg/L. The average outfall TSS values for these three feedings were 0.46 mg/L, 0.64 mg/L, and 1.93 mg/L. A harvesting event that occurred in the upper series of raceways had no effect on the outfall TSS concentration, or the peak load from this activity was missed. While harvesting and cleaning, farm employees took care not to disturb the solids on the bottom of the raceways and sediment traps, but unavoidably some disturbance occurred. Samples collected at the end of the raceway being cleaned had TSS concentrations of 0.46 mg/L to 10.12 mg/L. Samples taken at the confluence of the side stream and the trout farm outfall soon after cleaning had TSS concentrations of 1.38 mg/L to 5.00 mg/L. Because of the variability between the three different feeding activities and the high spike during no activity, the advisory panel decided not to allocate the point source loads to the various activities.

A load of 4.1 tons per year was estimated for the trout farm. This load may under-represent the true load because the fish were stressed by warm weather and eating less feed. The total trout farm loading was estimated by adding the load from the trout farm effluent and the load from the side stream. The addition of the load from the side stream may over-estimate the farm load since nonpoint and point sources influence this stream. Because the side stream receives effluent from the upper and lower series of raceways, it is necessary to consider this stream as being under the influence of the trout farm.

8.5 POLLUTION SOURCES

Table 8.2 presents the existing average annual organic solids load for Wallace Mill Stream.

Table 8.2 Existing organic solids loading in Wallace Mill Stream

Source Category	Organic Load (pounds per year)	Percent of Total Load
Headwaters (Spring)	0	0.0 %
Point Source (Trout Farm)	4,958	88.1 %
Nonpoint Source		
Pasture/Grassy Fields	532	9.5 %
Deciduous Forest	82	1.5 %
Residential	24	0.4 %
Roads	33	0.6 %
Total Existing Load	5,629	100 %

8.5.1 Natural Background Loads

Because four samples taken from the headwaters had no detection of TSS and stakeholders reported no known issues with turbidity or other water quality problems with the spring, no TSS loads were attributed to the background condition. Therefore, no organic solids load was attributed to the spring.

8.5.2 Point Source Loads

A single point source was documented in the Wallace Mill Stream watershed. This source is an aquaculture facility that raises trout for stocking and processing, but no processing takes place at the facility. The trout farm holds a general permit (Virginia Pollutant Discharge Elimination System Permit VAG131002) that requires quarterly monitoring of discharge flow, total suspended solids, and settleable solids. According to the general permit, the facility should monitor the effluent once every three months for the following parameters:

1) Estimate flow (million gallons per day, MGD) at the time of the sampling. There is no effluent limit for flow.
2) Report monthly average and daily maximum total suspended solids (TSS) from a composite sample, i.e., hourly grab samples, not to exceed eight grab samples, taken for the duration of an operating day, during periods of representative discharges including fish harvesting and/or unit cleaning or solids removal operations, and combined to form one representative sample. The monthly average must not exceed 10 mg/L, and the daily maximum must not exceed 15 mg/L.

3) Report average and daily maximum settleable solids from a composite sample, i.e., hourly grab samples, not to exceed eight grab samples, taken for the duration of an operating day, during periods of representative discharges including fish harvesting and/or unit cleaning or solids removal operations, and combined to form one representative sample. The monthly average must not exceed 0.1 mL/L, and the daily maximum must not exceed 3.3 mL/L (DEQ 1998a).

A load of 23.3 tons per year of TSS would be expected if the facility continuously discharged its daily maximum allowed TSS concentration (15 mg/L). A TSS load of 4.1 tons per year as measured by the TMDL study monitoring was used in the TMDL calculation. The TSS load was converted to organic solid load by multiplying the TSS load by the estimated volatile solids fraction, 60 percent. The calculated organic solids load, therefore, is 4,958 pounds per year.

8.5.3 Nonpoint Source Loads

Sediment loads for the nonpoint sources in the affected stream riparian zone were estimated using the Revised Universal Soil Loss Equation (RUSLE) and a sediment delivery ratio of 0.9. The riparian zone was defined as a 300-foot land strip on each side of the stream segment. The RUSLE takes into account the vegetative cover, best management practices, slope, soil erodibility, and amount and intensity of rainfall. These factors are each assigned a numeric value, and the product of these values is multiplied by the riparian land acreage to determine an annual sediment load. Additional information about the RUSLE factors and an example calculation for Ingleside Spring Branch, the organic solids load reference, can be found in Appendix I.

The estimated nonpoint source (NPS) sediment load was converted to the organic solid load by multiplying the NPS sediment load by the percent organic matter content of soil. Five percent organic matter content was used to account for the labile organic matter content originating from the nonpoint sources. Land use, sediment yield, and organic load within the 600-foot riparian zone (65 acres) for Wallace Mill Stream are described in Table 8.3. The pasture category also includes transitional lands, which refers to previously forested lands that have been cleared recently (within the last 5-10 years) and are currently used as pasture.

Table 8.3 Land use, area, sediment yield, and organic solids load for the riparian area of Wallace Mill Stream.

Land Use	Percent of Area	Sediment Yield (tons/year)	Organic Solids Load (pounds/year)
Pasture	78 %	5.3	532
Deciduous Forest	16 %	0.8	82
Residential	4 %	0.2	24
Roads	2 %	0.3	33
Total	**100 %**	**6.7**	**671**

8.6 TMDL CALCULATION

Virginia does not currently have water quality criteria for organic solids. For this reason, a reference watershed approach was used to identify the TMDL target loads (See Section 3.4). The reference watershed approach was modified to consider only a part of the watershed—the stream riparian zone, a 300-foot land strip on each side of the stream segment. For the TMDL calculations, Ingleside Spring Branch, the benthic reference stream, was used to set the target for the organic solids load. Owing to differences in the stream lengths between the impaired segment and the reference stream, the target load estimate was adjusted to compensate for differences between the riparian area of Wallace Mill Stream and Ingleside Spring Branch. This adjustment was necessary because riparian size influences sediment delivery, and consequently organic solids load, to the stream.

By comparing Wallace Mill Stream to a similar non-impaired watershed (Ingleside Spring Branch) and allowing for a five percent margin of safety, the amount of loading that will meet the water quality objectives is 3,278 pounds per year.

The TMDL established for Wallace Mill Stream consists of a point source wasteload allocation (WLA), a nonpoint source load allocation (LA), and a margin of safety (MOS) (Table 8.4). The TMDL equation is as follows:

TMDL = WLA + LA + MOS

The WLA portion of this equation is the total loading assigned to point sources. The LA portion represents the loading assigned to nonpoint sources. The MOS is the portion of loading reserved to account for any uncertainty in the data and the computational methodology used for the analysis. An explicit MOS of five percent was used in the TMDL calculations to provide an additional level of protection for aquatic life.

Table 8.4 TMDL for Wallace Mill Stream

Watershed	Pollutant	TMDL (pounds/yr)	WLA (pounds/yr)	LA (pounds/yr)	MOS (pounds/yr)
Wallace Mill Stream	Organic Solids	3,451	2,814	464	173

8.7 LOAD ALLOCATION

Load allocations were assigned to each source category in the watershed based on information from the visual survey, knowledge of best management practices, and professional judgment.

Loadings from certain source categories were allocated according to their existing loads. For instance, loads from forest areas represent the natural condition that would be expected to exist; therefore, the loading from forests was not reduced. The loads from the residential area and roads were not reduced because they are small (less than one percent) in comparison to the total load. The organic solids allocation scenario for Wallace Mill Stream is presented in Table 8.5.

Table 8.5 Organic solids load allocations for Wallace Mill Stream

Source Category	Organic Solids Load Allocation (lbs/yr)	Percent Reduction
Headwaters (Spring)	0	0 %
Point Source (Trout Farm)	2,814	43 %
Nonpoint Sources		
Pasture	325	39 %
Deciduous Forest	82	0 %
Residential	24	0 %
Roads	33	0 %
TMDL Load (Minus MOS)	3,278	

8.8 LOAD REDUCTION SCENARIO

The Best Management Practices (BMPs) described below should be sufficient to reduce the needed organic solids load to the TMDL target. The developed implementation plan should consider all BMPs and utilize the combination that works best for this impaired stream section. A summary of the TMDL implementation strategy and recommended BMPs are described in Section 13.2.

8.8.1 Point Source Reduction Scenario

Some BMPs such as the use of high energy feed (42% protein and 16% fat content) are being used at the trout facility on Wallace Mill Stream. These implemented BMPs should be continued. Additional BMPs are needed to meet the TMDL organic solids load of 2,839 pounds per year. General suggestions follow, but site-specific implementations plans should be developed for this trout facility (Table 8.6).

The combined use of the suggested BMPs: 1) redesigned end-of-raceway settling basin, 2) frequent cleaning of sediment traps and the settling basin, and 3) properly constructed, used, and maintained off-line settling basins would be expected to reduce the existing organic solids effluent load (4,958 pounds per year) by 82 percent and allow only 912 pounds per year of organic solids from the trout farm to enter the stream. The TMDL goal is to reduce the existing load to 2,814 pounds per year of organic solids, a 43 percent reduction. Therefore, the combined use of the proposed BMPs is expected to meet the TMDL goal. A description of the proposed BMPs follows.

Settling Basin:

A settling area below the last raceway is currently used, but it should be redesigned to increase the efficiency in TSS and organic solids removal. It may be redesigned to direct the effluent into a diversion channel when cleaning the settling basin. Boardman et al. (1998) found that sediment basins with 10-minute detention times are able to significantly reduce spike loadings but cannot reduce TSS concentrations during average flow conditions. Reductions during normal conditions require 20-minute detention times. Twenty-minute detention times resulted in 96 percent removal of TSS, and 30-minute detention times reduced TSS concentrations by almost 98 percent. Redesigning the settling basin to aim for efficiencies observed with the twenty-minute detention time in the pilot plant study is recommended.

The use of baffles in the settling basin that are spaced appropriately (to prevent scouring yet promote plug flow) is suggested as an economical way to increase flow length within the confines of a relatively small space so that solids may settle. The efficiency of the settling basin will depend on how clean it is kept. Effluent during the cleaning of a settling basin in this TMDL study (at another facility) had a TSS concentration of 53 mg/L when the basin was full (12 inches deep with solids) and a TSS concentration of 8 mg/L when the basin had only 0.5 inches of solids.

Off-line Settling Basins/Land Application:

Solids removed from sediment traps and settling basins must not be allowed to enter the impaired stream or tributaries to the impaired stream. These concentrated slurries should be treated in off-line settling basins or be land applied in such a way that runoff will not wash the solids to nearby streams. Ponds are available on site so converting these to off-line settling basins may prove to be an economical means to meet the TMDL goal. Idaho DEQ requires off-line settling basins to have 85 percent TSS removal efficiency so following the designs, use, and suggested maintenance outlined in *Idaho Waste Management Guidelines for Aquaculture Operations* should provide similar results.

8.8.2 Nonpoint Source Reduction Scenario

Of the Wallace Mill Stream riparian area (65 acres), the pastureland constitutes 51 acres. Visual assessment indicated that the nonpoint source (NPS) sediment load, and consequently the NPS organic solids load, to Wallace Mill Stream mostly originates from the stream section along the impaired stream characterized by eroded areas, inadequate buffer, and cattle access to the stream. The NPS required reduction of organic solids load from the current 532 pounds per year from pasture areas should to be reduced to 325 pounds per year (39 percent reduction). To achieve the NPS required reduction of the organic solids load, the following BMPs are proposed.

The pasture along 800 feet of the impaired stream segment should be converted to a filter strip of grass and canopy. Installation of this BMP should improve the land cover condition, decrease runoff velocity, increase infiltration into the soil, and trap solids before they enter the stream. In addition, fences and cattle stream crossings should be installed to reduce cattle access to stream. Fencing and crossing BMPs should improve eroded stream banks and reduce direct manure deposition in the stream. Literature supports the positive effects of buffer strips on preventing sediment transport to streams (Dillaha et al. 1986) and positive impacts of cover condition on Sediment Delivery Ratio (SDR) (Novotny and Olem 1994).

A BMP that consists of a 100-foot buffer grass strip with canopy (50 feet on each side of the stream) installed along the riparian area of the 800-foot section of the impaired stream will use 1.84 acres of the total pasture area in the riparian area (51 acres). The BMP installation is expected to reduce the Management Practice (P) factor in the RUSLE calculation to 0.7. The C factor changes to 0.0029, a weighted average of the values in the pasture and buffer strip. Other RULSE factors remain the same (K = 0.27, LS = 1.1, R = 130); the SDR becomes 0.8. The management practice therefore will result in 3.2 tons per year sediment yield (323 pounds per year organic solids yield), which reduces the load to meet the 39 percent reduction needed.

9 MONTEBELLO SPRING BRANCH TMDL

9.1 INTRODUCTION

In 1998, an unnamed tributary referred to as Montebello Spring Branch, was declared impaired for failing to support aquatic life. The impaired segment begins at a fish cultural station discharge and continues downstream for 0.02 miles (about 100 feet) to the confluence with Mill Creek. The stream received a priority of "medium" for not/partially supporting the aquatic life use (DEQ 1998b).

9.1.1 Watershed Background

Montebello Spring Branch is a first order stream that discharges into Mill Creek, which discharges into the upper Tye River. The Montebello Spring Branch watershed is part of the James River hydrologic unit number 02080203 with watershed identification code of VAV-H09R. Waters from the James River Basin eventually flow into the Chesapeake Bay.

The benthic macroinvertebrate surveys of the impaired segment of Montebello Spring Branch were compared to surveys taken from a reference stream to obtain the impaired status. The reference stream is a part of Mill Creek, the receiving stream. Both streams are located in Nelson County, Virginia in the Blue Ridge Mountains ecoregion.

Watershed delineation for both the impaired stream segment and the reference stream followed natural topographic drainage divides (Appendix E). The watershed area for Montebello Spring Branch is about 290 acres, and the watershed area for the reference stream, Mill Creek, is approximately 1,300 acres. The land use of the Montebello Spring Branch watershed is primarily deciduous forest (94%). A trout rearing facility (2.5%), evergreen forest (1.5%), roads (1%), and residential (<1%) areas make up the remaining 6% of the land use. Route 690 (Fish Hatchery Road) and a private drive lie within the watershed. The land use for the watershed of Mill Creek is deciduous forest (68%), evergreens (27%), pastureland (4%), and service (< 1%). Water runoff from Route 690 drains to Mill Creek.

9.2 BENTHIC MONITORING

9.2.1 DEQ Benthic Monitoring

On October 18, 1995, DEQ personnel conducted biological monitoring (using Rapid Bioassessment Protocol (RBP) II) on Montebello Spring Branch below the fish cultural station discharge and at two stations on Mill Creek. The reference site was selected at a location on Mill Creek approximately 200 yards upstream of the confluence with Montebello Spring Branch. A second site on Mill Creek was also surveyed; this site was approximately 90 yards downstream of the confluence with Montebello Spring Branch. The station on Montebello Spring Branch was sampled about 10 yards upstream of its confluence with Mill Creek (Bolgiano 1995d).

The station on Montebello Spring Branch was designated as “severely impacted.” Few families of macroinvertebrates were observed in Montebello Spring Branch. There were no scrappers or shredders, indicating an ecological imbalance in the types of organisms found. There were also no Ephemeroptera, Plecoptera, or Tricoptera (EPT) in the sample, which are considered to be indicators of good water quality. Over 85 percent of the counted organisms were tubifex worms, and Asellidae (sow bugs) were the next most abundant taxa (Bolgiano 1995d).

Of the two sites sampled on Mill Creek, the macroinvertebrate community downstream of Montebello Spring Branch was degraded compared to that at the upstream station. The upstream station was characteristic of a near pristine environment. The downstream station on Mill Creek received a slightly lower habitat score because of a nearby road and a stream channel alteration. There were fewer pollutant intolerant taxa, such as Ephemeroptera and Plecoptera, and higher pollutant tolerant groups, like flatworms and tubifex worms, at the downstream site (Bolgiano 1995d).

Results from additional sampling in Montebello Spring Branch in 2000 found that conditions were unchanged from the 1995 survey. The benthic community was dominated by tubifex worms.

9.2.2 TMDL Benthic Monitoring

As a part of the TMDL study, it was recommended that a more in-depth benthic study be conducted to provide additional data for further evaluation of the impaired status of the streams. See Appendix A for more information.

Mill Creek (Reference Stream):

Additional benthic surveys were not conducted in Mill Creek. Instead, another possible reference site was evaluated, but the site did not prove to be as good a match. Because the past DEQ data using RBP II has provided the same general results as the TMDL benthic sampling for all other sites, the benthic community of Mill Creek is believed to be adequately described by the earlier DEQ data.

Montebello Spring Branch:

The benthic community at Montebello Spring Branch was dominated by isopods (sow bugs), oligochaetes (tubifex worms) and a physid snail. Isopods and oligochaetes were the dominant organisms in previous DEQ benthic surveys. These and most of the other common taxa are all "very tolerant" taxa, resulting in a mean HBI value of 8.4. The benthic community in

Montebello Spring Branch was different from that expected in a reference stream. Oligochaetes and isopods would occur in a reference stream but not to the extent found in this stream. Although no EPT taxa occurred in the stream, the substrate was not conducive to supporting those taxa.

9.3 VISUAL SURVEY

The objective of the visual survey was to document environmental conditions with potential to affect the benthic community. The visual survey involved observing and cataloging water and land conditions, land and water uses, and the changes that take place along defined stream segments (Appendix F).

Mill Creek (Reference Stream):

The visual survey of Mill Creek included its confluence with Montebello Spring Branch and upstream approximately 300 yards. This stretch of the creek encompasses the benthic reference location (200 yards upstream of the confluence). A forested buffer is on both sides of the stream, except where Route 690 crosses the stream. Drainage ditches from the road feed Mill Creek. Near the confluence with Montebello Spring Branch, Mill Creek passes under Route 690 through a concrete culvert. On the downstream side of the road, a small dam impounds the water. The impounded waters of Mill Creek are sometimes pumped to the headwaters of the fish cultural station.

Montebello Spring Branch:

Water from several springs, the main spring and at least three very small springs, flows through 34 concrete raceways (22 in the upper group and 12 in the bottom group) for raising trout. Water is pumped from Mill Creek to the spring box when needed to supplement the flow from the springs and ensure the trout have enough water. Used water from the raceways is discharged into Montebello Spring Branch, which then discharges into Mill Creek.

The visual survey revealed four observed environmental conditions. The trout facility provided the only point source discharge to the stream. Mats of periphyton were observed on the stream bottom throughout the entire impaired segment. An erosion site at the end of the impairment was about 30-feet in length and almost four-feet high at its tallest point. A four-inch diameter metal pipe crossed above the stream in one location.

9.4 PHYSICAL/CHEMICAL MONITORING

9.4.1 DEQ and Other Physical/Chemical Monitoring

The discharge monitoring reports provided by DEQ for September 1998 through November 2001, showed compliance with the permit. An average of the loads calculated from the reports suggests a load of 2.1 tons per year from the facility based on the total suspended solids (TSS) and flow estimates.

DEQ personnel took water samples from the effluent immediately before cleaning the main settling basin on February 21, 2001 and during the cleaning event. The TSS concentrations increased from 6 mg/L before the cleaning to 53 mg/L during the cleaning.

Boardman et al. (1998) obtained inlet, within farm, and outlet water quality data for three trout farms in Virginia from September 1997 to April 1998 on a bi-monthly basis. Their TSS findings are shown in Table 9.1. Using the average TSS concentrations from the farm effluents with the lowest and highest TSS concentrations (Farm A, 3.0 mg/L; Farm C, 5.8 mg/L) and a spring flow of 0.86 cfs (comparable to the spring flow in this study), a TSS load of 2.5 tons per year to 4.9 tons per year could be expected.

Table 9.1 Total suspended solids concentrations for trout farms A, B, and C. "Within Farm" refers to data obtained from the end of all active raceways in each farm.

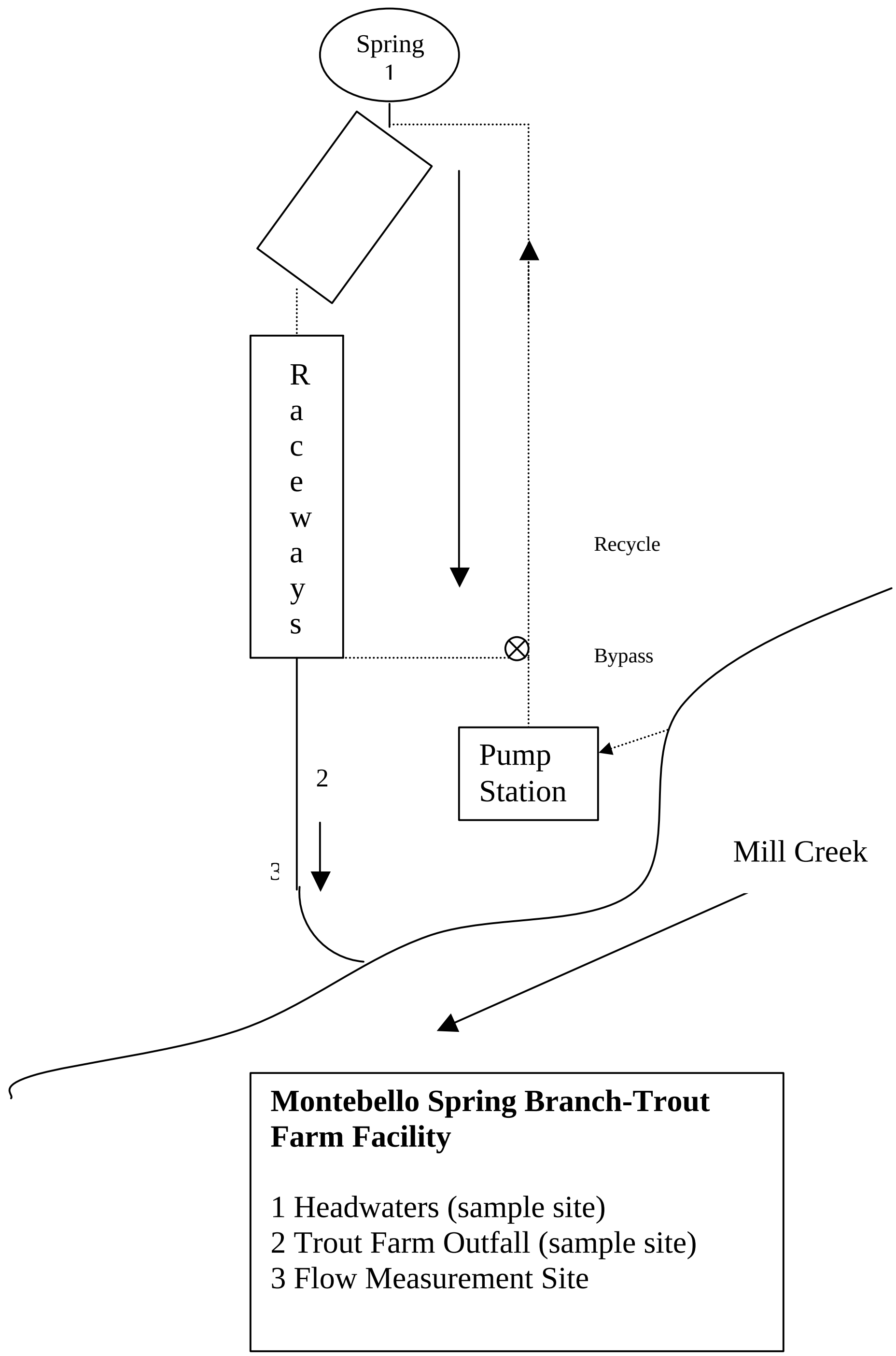
	Farm A			**Farm B**			**Farm C**		
(mg/L)	Inlet	Within Farm	Outlet	Inlet	Within Farm	Outlet	Inlet	Within Farm	Outlet
TSS range	0-1.1	0-30.4	0.8-6.0	0-1.8	0-43.7	1.5-7.5	0-1.5	0-28	4.1-62
TSS average	0.2	3.9	3.2	0.5	5.3	3.9	0.3	7.1	6.1*

*Two outliers removed for calculation of the average

9.4.2 TMDL Physical/Chemical Monitoring

Sampling at the trout facility for the TMDL study occurred from July 18-July 19, 2001, August 14-August 15, 2001, and on January 29, 2002. Samples were collected from the mixing box for the trout facility and the trout farm outfall (Figure 9.1). Samples were collected during the various activities that take place at the farm as described in Appendix G.

Figure 9.1 Diagram of sample collection sites and stream flow measurement site for the trout farm facility on Montebello Spring Branch. Not drawn to scale.



Sampling occurred under different levels of sediment pile-up in the main settling basin. The first set of samples was collected when the settling basin was approximately three-fourths full (sediment depth in the settling basin ranged from 0 to 14 inches in depth). The second set of samples was collected when the settling basin had about 0.5 inch of sediment in the bottom. The settling basin was almost full during the January sample collection, but measurements of the sediment depth were not taken.

Eight samples collected from the headwaters had an average TSS concentration of 0.17 mg/L (Appendix H). Six of the samples had no detectable levels of TSS (detection limit = 0.001 mg/L). One sample had a TSS value of 0.45 mg/L and another had a TSS concentration of 0.89 mg/L. It was not surprising that the headwaters showed some TSS levels because water from Mill Creek, which receives considerable overland flow, is mixed with the spring waters. Although it rained on July 18 and July 19, 2001, all the Montebello Spring Branch headwater samples and two of the Mill Creek samples had TSS concentrations of 0.00 mg/L. The last sample collected, in the afternoon of July 19, 2001, in Mill Creek had a TSS concentration of 18.57 mg/L. No afternoon sample was collected from the headwaters of Montebello Springs Branch.

Of the 66 samples collected from the outfall, seven had no detection of TSS. All but eight samples from the outfall were below 5.00 mg/L. The highest TSS sample taken from the outfall was 8.09 mg/L, which is below the permitted concentration of 15 mg/L. This sample was collected during cleaning of the settling basin. The results of samples collected during five feedings ranged from 0.00 to 5.51 mg/L. Harvesting appeared to have little affect on the TSS concentrations at the outfall.

Five feedings were sampled. Virginia Department of Game and Inland Fisheries (DGIF) personnel observed that the feed provided at 11:00 a.m. on July 19, 2001 was not being eagerly consumed so they reduced their feeding schedule to only once each day. The data support the observations made by the DGIF personnel as a clear trend of increasing TSS concentrations at the outfall was observed during this sampling period. The samples, taken at approximately five-minute intervals, increased steadily in TSS to about 5.50 mg/L. The other four series of feeding samples did not show a distinct trend.

While harvesting, farm employees took care not to disturb the solids on the bottom of the raceway, but unavoidably some disturbance occurred. Spikes in TSS concentrations from samples collected at the outfall were not evident following simulated harvests of the fish. However, three samples colleted at the end of the raceway where the fish harvest occurred had spikes of 8.74 mg/L, 11.01 mg/L, and 18.62 mg/L.

Cleaning of the main settling basin took place on August 14, 2001, when it had solids build-up of 0.5 inches. The settling basin is normally cleaned when it is about three-fourths full to completely full (9 to 12 inches deep). The cleaning on August 14, 2001 was for the purpose of our sample collection. Cleaning takes at least a half a day. Cleaning began at 9:45 a.m. and did not end until about 2:00 p.m. (with breaks in between). Samples collected at the end of the raceways showed elevated TSS values (1.57-8.09 mg/L). Five of the twelve samples collected during cleaning had TSS concentrations above 5.00 mg/L (Appendix H).

The results of the DEQ sampling during cleaning at this facility and the results of the TMDL sampling during cleaning at this facility suggest that the amount of solids in the settling basin affects the amount of solids entering the receiving stream. The DEQ monitoring on Montebello Spring Branch when the settling basin was full (about 12 inches in depth) had TSS concentrations that increased from 6 mg/L before the cleaning to 53 mg/L during the cleaning. Samples taken during the TMDL study period on Montebello Spring Branch, when the settling basin only had 0.5 inches of solids, increased only to 8.09 mg/L during the cleaning.

Because of the TSS variability between the five different feeding activities (average 0.85 to 3.46 mg/L), relatively high TSS concentrations obtained during no activity (up to 4.41 mg/L), and variable TSS values in the headwaters, the advisory panel decided that it would be unreliable to allocate the point source loads to the various activities. A total solids load of 1.5 tons per year was estimated for the point source from an average of the 66 TMDL study samples from the trout farm outfall.

9.5 HYDRAULIC LOAD

Low flows were identified as a critical stressor of the benthic macroinvertebrates for Montebello Spring Branch. The spring flows for Montebello Springs Branch are extremely variable, estimated from 20 gallons per minute (GPM) to 400 GPM in a given year. The trout facility is unable to rely on springs as its sole source of water, and generally pumps water from nearby Mill Creek to compensate for periods of low flow. Thus, the water levels in Montebello Springs Branch stay fairly constant. However, in extreme situations, when Mill Creek also runs low, the effluent from the trout facility is recirculated, and no water flows through Montebello Spring Branch. During these times, all aquatic life in the stream perishes.

Using best professional judgment, the aquatic biologists on the advisory panel, recommended a water depth in Montebello Spring Branch of at least two inches to support a viable benthic macroinvertebrate community. A depth of two inches is enough water to insure that the majority of the streambed is wetted, that there is sufficient flow (velocity) through the area, and enough water to give fish a chance to survive. Water depths as low as a quarter inch or less deep would allow some tolerant macroinvertebrate species to survive, but it would be a stressed community.

The flow condition for Mill Creek, the benthic reference stream, was used as a guideline for estimating the needed flow in Montebello Spring Branch. During the TMDL study, Mill Creek’s average depth was 0.25 ft (3 inches) and average velocity was 0.7 feet per second. Using the Mill Creek velocity and 2 inch water depth as a yardstick, the required flow rate in the impaired segment (average width 33 inches) is 0.32 cubic feet per second (about 144 GPM). This requirement exceeds the natural low flow (20 GPM) by about 7 times. It is probable, therefore, that under natural drought conditions, Montebello Springs cannot produce enough water to sustain aquatic life in Montebello Spring Branch.

Although the TMDL advisory panel did not recommend that a minimal hydraulic load be maintained in Montebello Spring Branch, DEQ and EPA will need to review the situation. A hydraulic load variance may be granted, or the facility may need to discharge to Montebello Spring Branch at least the amount of spring flow at all times.

9.6 POLLUTION SOURCES

Table 9.2 presents the existing average annual sediment load for Montebello Spring Branch.

Table 9.2 Existing organic solids loading in Montebello Spring Branch

Source Category	Organic Load (pounds per year)	Percent of Total Load
Headwaters (Spring)	14	0.7 %
Point Source (Trout Farm)	1,823	94.9 %
Nonpoint Source		
Deciduous Forest	43	2.2 %
Gravel Drive	40	2.1 %
Total Existing Load	1,920	100 %

9.6.1 Natural Background Loads

An organic solids load of 14 pounds per year is estimated for the headwaters of Montebello Spring Branch. The load was calculated from the average TSS concentration of eight samples collected from the headwaters (0.17 mg/L) and a flow estimation of 0.86 cubic feet per second (cfs). The organic content was considered to be 5 percent of the total solids load as estimated from the TSS concentrations.

9.6.2 Point Source Loads

A single point source discharge enters Montebello Spring Branch: effluent from a fish cultural station. The facility is state owned and is operated by the Virginia Department of Game and Inland Fisheries (DGIF). At the facility, brook, brown, and rainbow trout are grown from the fingerlings stage to stocking size. The fish are stocked in public accessible trout streams in waters east of the Blue Ridge Mountains from Amherst County, north. The Montebello station leads the state in stocking urban waters, and it is also one of the most widely visited state fish cultural stations in Virginia (DGIF 2001).

The fish cultural station holds Virginia Pollutant Discharge Elimination System (VPDES) Permit Number VA0006505, an individual permit, for the discharge of wastewater to Mill Creek. Individual permits generally require monthly monitoring, but quarterly monitoring is required for the fish cultural station because the facility has a 20-year record of compliance. The discharge flow is estimated on a quarterly basis at the time of discharge sampling. The discharge water is sampled and analyzed for total suspended solids (TSS), settleable solids (SS), biochemical oxygen demand (BOD_5), ammonia, pH, dissolved oxygen (DO), and total residual chlorine (TRC, DEQ 1997c). The monitoring requirements for nitrogen and phosphorus have been removed from the permit because they only apply to nutrient-enriched State Waters, and the receiving stream is not designated as nutrient-enriched.

According to the VPDES permit, DGIF personnel are required to sample during periods of representative discharges and during discharges associated with fish harvest and/or solids removal. The BOD_5, pH, dissolved oxygen, and TRC parameters are analyzed from grab samples. The TSS, SS, and ammonia parameters are analyzed from composites of five grab samples collected during an eight-hour period (5G/8H). The discharge permit requirements are as follows (DEQ 1997c):

- Estimate flow (million gallons per day, MGD) at the time of the sampling. There is no effluent limit for flow.
- The monthly average TSS concentration must not exceed 10 mg/L, and the maximum daily TSS concentration must not exceed 15 mg/L.
- The monthly average SS concentration must not exceed 0.1 ml/L, and the maximum daily SS concentration must not exceed 0.5 ml/L.
- The monthly average BOD_5 must not exceed 8 mg/L.
- The monthly average for ammonia must not exceed 2.2 mg/L, and the daily maximum limit for the ammonia concentration is 3.79 mg/L.
- The pH for the discharge must be maintained between 6 and 9.
- The discharge DO must be greater than or equal to 7.0 mg/L.

DGIF personnel reported the occasional use of Chloramine-T in the past to control diseases, such as Bacterial Gill Disease and Columaris Disease. Because the use of Chloramine-T is infrequent and the duration of its use is generally less than two hours, the halogen ban section (9 VAC 25-260-110) does not apply to this facility. When Chloramine-T is in use, the facility is to operate decholorination equipment when the dosing begins and continue until the treated water has been flushed from the system, and the effluent is to be monitored for TRC (DEQ 1997c). According to facility personnel, Chloramine-T is no longer used.

A TSS load of 12.7 tons per year is estimated from the daily maximum TSS concentration of 15 mg/L and flow estimation of 0.86 cfs. A TSS load of 1.5 tons per year is estimated from the average TSS concentration obtained during the TMDL sampling period and average stream flow of 0.86 cfs. A load of 1,823 pounds per year was used in the TMDL calculation based on the TMDL study average TSS concentration, average measured flow, and 60 percent organic content.

9.6.3 Nonpoint Source Loads

Sediment loads for the nonpoint sources in the affected stream riparian zone were estimated using the Revised Universal Soil Loss Equation (RUSLE) and a sediment delivery ratio of 0.9. The riparian zone was defined as a 300-foot land strip on each side of the stream segment. The RUSLE takes into account the vegetative cover, best management practices, slope, soil erodibility, and amount and intensity of rainfall. These factors are each assigned a numeric value, and the product of these values is multiplied by the riparian land acreage to determine an annual sediment load. Additional information about the RUSLE factors and an example calculation for Ingleside Spring Branch, the organic solids load reference, can be found in Appendix I.

The estimated nonpoint source (NPS) sediment load was converted to the organic solid load by multiplying the NPS sediment load by the percent organic matter content of soil. Five percent organic matter content was used to account for the labile organic matter content originating from the nonpoint sources. Land use, sediment yield, and organic load within the 600-ft riparian zone (2.7 acres) for Montebello Spring Branch are described in Table 9.3.

Table 9.3 Land use, area, sediment yield, and organic solids load for the riparian area of Montebello Spring Branch.

Land Use	Percent of Area	Sediment Yield (tons/year)	Organic Solids Load (pounds/year)
Deciduous Forest	97 %	0.4	43
Gravel Drive	3 %	0.4	40
Total	**100 %**	**0.8**	**83**

9.7 TMDL CALCULATION

Virginia does not currently have water quality criteria for organic solids. For this reason, a reference watershed approach was used to identify the TMDL target loads (See Section 3.4). The reference watershed approach was modified to consider only a part of the watershed—the stream riparian zone, a 300-foot land strip on each side of the stream segment. Ideally, the benthic reference site would be used to set the organic solids target because the characteristics, particularly the chemical/physical characteristics, should be most similar.
Mill Creek is the benthic reference stream for Montebello Spring Branch but was not used as the organic solids reference in the TMDL calculations. In terms of TDS, alkalinity, and hardness,

Mill Creek and Montebello Spring Branch are similar. However, a target organic solids load of 38 pounds per year would be obtained using Mill Creek as the organic solids load reference for Montebello Spring Branch. The organic solids load from runoff in the deciduous forest portion (and disregarding runoff contributions from the gravel drive and the point source) of the Montebello riparian buffer area yields 43 pounds per year of organic solids. Mill Creek therefore is not a suitable reference for setting the organic solids load target. Consequently, Ingleside Spring Branch, a non-impaired, spring-fed reference stream with the same flow classification as Montebello Spring Branch, was used.

Owing to differences in the stream lengths between the impaired segment and the organic solids reference stream, the target load estimate was adjusted to compensate for differences between the riparian area of Montebello Spring Branch and Ingleside Spring Branch. This adjustment was necessary because riparian size influences sediment delivery, and consequently organic solids load, to the stream.

By comparing Montebello Spring Branch to a similar non-impaired watershed (Ingleside Spring Branch) and allowing for a 5 percent margin of safety, the amount of organic solids loading that will meet the water quality objectives is 134 pounds per year. When this value is met, Montebello Spring Branch is expected to meet its aquatic life use.

The TMDL established for Montebello Spring Branch consists of a point source wasteload allocation (WLA), a nonpoint source load allocation (LA), and a margin of safety (MOS) (Table 9.4). The TMDL equation is as follows:

TMDL = WLA + LA + MOS

The WLA portion of this equation is the total loading assigned to point sources. The LA portion represents the loading assigned to nonpoint sources and includes loads from the headwaters. The MOS is the portion of loading reserved to account for any uncertainty in the data and the computational methodology used for the analysis. An explicit MOS of five percent was used in the TMDL calculations to provide an additional level of protection for aquatic life.

Table 9.4 TMDL for Montebello Spring Branch

Watershed	Pollutant	TMDL (pounds/yr)	WLA (pounds/yr)	LA (pounds/yr)	MOS (pounds/yr)
Montebello Spring Branch	Organic Solids	141	37	97	7

9.8 LOAD ALLOCATION

Load allocations were assigned to each source category in the watershed. Loadings from certain source categories were allocated according to their existing loads. For instance, loads from the forest represent the natural condition that would be expected to exist; therefore, the loading from the forest was not reduced. The load from the gravel drive was also not reduced because it is small in comparison to the load from the point source, and we know of no easily implementable best management practice to control the organic solids load from this source. All of the reductions, therefore, would come from the point source. The organic solids load allocation scenario for Montebello Spring Branch is presented in Table 9.5.

Table 9.5 Organic solids load allocations for Montebello Spring Branch

Source Category	Organic Solids Load Allocation (lbs/yr)	Percent Reduction
Headwaters (Spring)	14	0 %
Point Source (Trout Farm)	37	98 %
Nonpoint Sources		
Deciduous Forest	43	0 %
Gravel Drive	40	0 %
TMDL Load (Minus MOS)	134	

9.9 LOAD REDUCTION SCENARIO

Because the loads of organic solids are either natural or relatively small, except for loads from the trout facility, all reductions in the scenario come from the trout facility. The goal is to reduce the organic solids load from the trout facility to 37 pounds per year. A summary of the TMDL implementation strategy and recommended BMPs are described in Section 13.2.

The state had a Facility Improvements and Options plan developed for the trout facility located on Montebello Spring Branch. The report recommends that a second settling basin could be added in the middle section of the raceways, and a rotary drum screen could be used. The developed plan should be utilized in the decision making process of the implementation plan.

Some Best Management Practices (BMPs), such as the use of high energy feed (42% protein and 16% fat content), are being used at the trout facility on Montebello Spring Branch. These implemented BMPs should be continued. Additional BMPs are needed to meet the TMDL target of 98 percent reduction in organic solids loads. General suggestions follow, but site-specific implementations plans should be developed for this trout facility.

The BMPs described below should be sufficient to reduce the needed organic solids load to the TMDL target. The developed implementation plan should consider all BMPs and utilize the combination that works best for the farm given the known flow characteristics, available space (land), number of farm personnel, TSS concentrations, etc.

The combined use of the suggested BMPs: 1) redesigned sediment traps, 2) redesigned end-of-raceway settling basin, 3) frequent cleaning of sediment traps and the settling basin, and 4) proper land application of solids would be expected to reduce the existing organic solids effluent load (1,823 pounds per year) by 98.4 percent and allow only 29 pounds per year of organic solids from the trout farm to enter the stream. The TMDL goal is to reduce the existing load to 37 pounds per year of organic solids, a 98 percent reduction. Therefore, the combined use of the proposed BMPs is expected to meet the TMDL goal. A description of the proposed BMPs follows.

Sediment Traps:

Sediment traps (quiescent zones) are currently in use below raceways at the facility but should be redesigned for higher efficiency (e.g., using designs outlined in *Idaho Waste Management Guidelines for Aquaculture Operations* (IDEQ 1998)). In a study by Boardman et al. (1998), a trout farm raceway with a sediment trap had a detention time of 24 seconds, an inadequate time for most solids in the effluent to settle. They found that sediment traps are inefficient because of 1) insufficient surface area, 2) small detention time, and 3) infrequent cleanings. Redesigning the trap should increase the efficiency and result in more solids removal. Experiments of redesigned sediment traps could be incorporated into the TMDL implementation plan. Facility personal attempt to clean the sediment traps once a week. This practice should be continued, and the frequency of cleaning should be altered according to production changes within the facility (increased cleaning frequency with increases in feed amounts) and results of follow-up monitoring. An estimated 20 percent reduction in solids loading could occur with more frequent cleanings and the use of more effective traps (Experiments are needed to test this reduction estimation).

Settling Basin:

A settling basin (formerly used raceway) below the last raceway is currently used, but it should be redesigned to increase the efficiency in TSS and organic solids removal. It could be designed to allow the effluent to be directed into a diversion channel when cleaning the settling basin. Boardman et al. (1998) found that sediment basins with 10-minute detention times are able to significantly reduce spike loadings but cannot reduce TSS concentrations during average flow conditions. Reductions during normal conditions require 20-minute detention times. Twenty-minute detention times resulted in 96 percent removal of TSS, and 30-minute detention times reduced TSS concentrations by almost 98 percent. Redesigning the settling basin to aim for efficiencies observed with the thirty-minute detention time in the pilot plant study is recommended unless other practices are used in conjunction with the proposed BMPs to reduce the total load from the facility.

The use of baffles in the settling basin that are spaced appropriately (to prevent scouring yet promote plug flow) is suggested as an economical way to increase flow length within the confines of a relatively small space so that solids may settle. Like the sediment traps, the efficiency of the settling basin will depend on how clean it is kept. Effluent during the cleaning of the settling basin had a TSS concentration of 53 mg/L when the basin was full (12 inches deep with solids) and a TSS concentration of 8 mg/L when the basin had only 0.5 inches of solids.

Off-line Settling Basins/Land Application:

Solids removed from sediment traps and settling basins must not be allowed to enter the impaired stream or tributaries to the impaired stream. These concentrated slurries should be treated in off-line settling basins or be land applied in such a way that runoff will not wash the solids to nearby streams. Land application is currently used at this site. Land application practices should be reviewed to make certain the collected solids are prevented from entering the impaired stream or its tributaries in runoff from the applied field.

10 CONSIDER CRITICAL ENVIRONMENTAL CONDITIONS

A TMDL must consider critical environmental conditions for stream flow, loadings, and water quality parameters—that is, the most environmentally stressful times that may occur at the site. The purpose is to ensure that water quality is protected even during the most stressful times. It is necessary therefore to determine how the identified critical stressors may impact the benthic macroinvertebrate community during critical environmental conditions.

10.1 FLOW

Natural stresses to benthic macroinvertebrates include changes in water depth and velocity. Benthic macroinvertebrate communities survive well or can recover following high flow conditions. Communications with the trout producers have indicated that on occasion, floods have washed away the trout and filled the raceways with debris and sediment. Such extreme events were not incorporated into the TMDL calculation because extreme high flows were considered natural events, from which the benthic macroinvertebrate community would be expected to recover given sufficient time. Smaller floods may scour out the settling-basins at the trout facilities and send very high loads of organic solids into the stream if the settling-basins are not cleaned frequently.

Low flows are generally most stressful for benthic macroinvertebrates. Stakeholders provided the information necessary to determine that the water quality data obtained for this report were collected during periods of critical low flow conditions. The stakeholders were asked to estimate the average yearly flow from the spring (gallons per minute, GPM), estimate monthly averages of spring flow for a typical year, and indicate the consistency of the spring flow. All stakeholders reported that water levels had dropped in recent years, particularly in the last two years. The flow levels for Cockran Spring Branch and Lacey Spring Branch during the sampling periods were 30-50 percent below the estimated normal flows. As one stakeholder commented, "We are at an all-time low at the present." The springs that feed Pheasanty Run and Wallace Mill Stream were less affected by the dry conditions, indicating that these springs have consistent flows even under dry conditions.

10.2 LOADS

Loadings from the trout facilities (point sources) are likely to be highest when feeding rates are highest or when overfeeding fish. The management of the different trout facilities varies somewhat, but in general the trout producers are able to feed more when water levels are high, particularly when water temperatures are cool. Thus, the impact on benthic macroinvertebrates from the trout facilities is expected to be higher during consistently higher flows. As described above, the TMDL sampling period occurred during low flow periods so the observed loads were expected to be lower than if the sampling had occurred during higher flows. For this reason, discharge monitoring report (DMR) data, which included data from different seasons and different years, were reviewed. Only reports from the past two or three years were examined because many of the facilities began using high energy feeds, which produces less waste, in the past two to three years. The estimated average annual loads calculated from the DMR data were compared to the loads calculated from the TMDL study data.

Loadings from nonpoint sources are expected to be highest following precipitation events, when runoff is highest and the stream carries more sediment. Higher loads from nonpoint sources that occur after precipitation events are included in the nonpoint source estimates calculated from the RUSLE.

10.3 W ATER QALITY PARAMETERS

Loch et al. (1996) found the stress on stream benthic organisms from aquaculture effluent to be greatest during periods of high temperatures (in association with low flows). To address the critical water quality periods, therefore, water sampling for the TMDL study was conducted during the summer months when water temperatures are expected to be highest. Accordingly, in the present study, dissolved oxygen levels in particular were measured in the summer.

11 CONSIDERATION OF SEASONAL VARIATIONS

In this TMDL report, summer and winter water monitoring of physical/chemical parameters was conducted to incorporate seasonal variations in the decision making process. The seasonality was also addressed for estimating point and nonpoint source loads. For point sources, seasonality was incorporated in terms of the amount of feed provided at different times of the year. Discharge-permit data, which span January 1998-December 2001, were reviewed and used as a guide for expected annual loads. For the nonpoint source determination, seasonality was incorporated in the calculation of the C and R parameters of the RUSLE.

12 MARGIN OF SAFETY

For determining loads from point sources, the maximum permitted concentration and average flows are often used. The calculation is incorporated as a safety factor because it is assumed that the discharger could increase future production of waste to the maximum permitted level. For the trout farms, however, this is not the case. The flow of water from the spring, not the amount of permitted discharge, limits production. The DEQ reports compliance with the permit limits by the trout farms, some for over 20 years of monitoring, and the TSS concentrations are almost always less than a third the maximum daily limit. The trout farms studied for the TMDLs are currently operating at their maximum production for the amount of available flow from the spring and do not foresee expanding their business in the next five to ten years. The point source contributions from the aquaculture facilities were therefore based on monitoring results and not on permit limits.

In the TMDL reports, an explicit margin of safety (MOS) of 5 percent was used: the target annual organic solids load was obtained by subtracting 5 percent of the load from the reference condition. For example, if the annual organic solids load in the reference condition was 100 pounds per year, 5 pounds per year (5 percent) of that condition was allocated to the MOS. The target annual organic solids load became 95 pounds per year and was distributed between the point and nonpoint sources based on obtained information (e.g., trout farm management practices, riparian vegetative cover condition) and best professional judgment.

13 REASONABLE ASSURANCE OF IMPLEMENTATION

Implementation plans can be developed from the information in this report that will improve water quality. However, implementation decisions based on the conclusions of this TMDL report should recognize and accommodate the uncertainties in the analyses. Carefully targeted monitoring and further analysis of the collected data will increase our understanding the benthic community as it responds to load reductions of organic solids.

13.1 UNCERTAINTIES IN THE TMDL ANALYSIS

Some of the uncertainties that should be considered in the TMDL implementation decision-making are described below.

13.1.1 Uncertainty in Target Selection

There is significant uncertainty in the biomonitoring and organic solids load target selection. It is impossible to select a comparable reference site that exactly matches the targeted stream characteristics. As was described earlier in this report, the headwaters of the impaired streams are springs that have unique water chemistry. Therefore, the natural water chemistry of the reference stream is not identical to that of the impaired stream. There are also significant differences between the reference streams and the listed impaired segments in the watershed sizes, physical characteristics, and flow rates. In summary, sufficient data are lacking to describe the composition of the benthic community in the listed impaired segments prior to the introduction of human activity, presuming that this is the target to be sought.

13.1.2 Uncertainty of Natural Stressors

There is uncertainty regarding the impact of major storm events that discharge significant amounts of runoff and sediment into the stream segment. One trout producer has observed high turbidity water in the headwaters during and after large storms. Several producers reported occasional high sediment loads in the raceways and impaired streams from runoff upstream of the spring following extremely heavy precipitation events (generally associated with hurricane storms). The impact of major storms on benthic macroinvertebrates is unknown and could not be quantified during this TMDL study. However, it can be speculated that large sediment volumes resulting from large storms could affect the benthic biota of the studied streams even if the trout farms were not present.

13.1.3 Uncertainty in Effluent Monitoring

One advantage of biomonitoring is that the benthic community integrates acute and chronic impacts to the stream, whereas chemical monitoring provides only a "snap shot" of the water quality. There are two likely ways the organic solids in the trout farm effluent enter the receiving stream: 1) in the dilute, but continuous addition to the stream, and 2) episodic events where large amounts of organic solids enter the stream in a short time period. The water sample collection for the TMDL study may have missed events that were not missed by the benthic community.

The water sample schedule used in the TMDL study was designed to capture episodic peaks during daily routine operations at the facilities. Because of the dilute nature of the effluent, timing of the sample collection was difficult to determine from changes in the visual appearance of the effluent. This was particularly true at the facilities with larger flows. Because concentration spikes are short in duration, monitoring was set at approximately five-minute intervals. The goal was to capture the concentration peaks from the lowest raceway, the one with the most impact on the stream. It is likely that peaks attributed to the daily activities were missed in the sample collection.

It is possible that one or two major cleaning events during the year could release large amounts of organic solids to the stream. The monitoring conducted for the TMDL report did not capture the effect from such episodic events. In the single instance that monitoring occurred when the main settling basin was being cleaned, the settling basin was almost empty and no large concentration spikes were obtained. (The monitoring results indicate that keeping the settling basin clean could prevent large spikes from entering the stream during cleaning events.)

13.1.4 Uncertainty of Organic Content

Volatile solids were not measured in the spring, effluent, and stream samples. Instead the organic solids loads were determined from estimates of organic content. It is likely the estimates do not represent the true organic content, although the estimates are believed to provide an accurate indication of the amount of organic material. For example, the 60 percent organic content estimated for the trout farm effluent is believed to be lower than the true amount. However, the percentage is still high and much larger than the estimated 5 percent organic content attributed to the nonpoint sources.

13.1.5 Uncertainty of BMP Effectiveness

Research by Boardman et al. (1998) was used in calculating the reduction loads for many of the BMPs for the trout facilities. In their report, they expressed caution in expecting similar results from full-scale applications as seen in their laboratory scale experiments and pilot plant studies. The actual success of the BMPs will depend on the conditions at the trout farm, including the flow, TSS concentration, temperature, wind, and many other factors.

13.2 TMDL IMPLEMENTATION STRATEGIES

Organic solids were identified as the likely benthic macroinvertebrate critical stressor in all six impaired streams. This conclusion was based on 1) the benthic monitoring results in the impaired segments, 2) visual observations of accumulated solids in the trout farm raceways and the listed stream segments, 3) a literature review of trout farm effluent effects on stream water quality, and 4) data collected for the TMDL report.

Lowering the level of organic solids input into the stream should lead to an improvement of the benthic community. However, the desired amount of reduction to restore the benthic macroinvertebrate community is unknown at this time because of the uncertainties identified earlier. In addition, it may be necessary to incorporate controls that are technologically practical and affordable to the small scale trout farm producers when setting the targets.

To meet the current TMDL implementation requirements, an adaptive management approach is recommended. Under this approach, the trout farm operators would implement a series of solids management practices. Other point source and nonpoint source management practices should be put in place where applicable. Follow-up monitoring of organic and solid concentrations (and loads) in farm effluents and the listed segments would be used to estimate load reductions. Annual benthic monitoring by DEQ would provide the necessary information about changes to the benthic macroinvertebrate community.

A combination of management practices should be tailored to each specific site. The following management practices are recommended.

13.2.1 Point Source Reductions

The implementation plan for each farm should be site specific because of unique facility and management characteristics. Boardman et al. (1998) made several general recommendations to improve the water quality of aquaculture effluents based on their research. Their summarized recommendations are below.

1. Sediment traps should be installed at the end of every active raceway. Design of traps is described by IDEQ [IDEQ1998], but configuration and space requirements are flexible.
2. Sediment traps should be cleaned on a regular basis as determined by the amount of feed and visual observation. Cleaning traps regularly will help to maintain effectiveness.
3. Settling basins should be installed at the end of each train of raceways. An overflow rate of 48.9 m^3/m^2 day should be provided. Basins should have screens and weirs to promote

quiescence. Baffles should be installed to promote plug flow and, when and where practicable, to provide walkway access around the settling tank. A diversion channel should be provided to prevent TSS effluent spikes during tank cleaning.

4. Settling tanks will also need to be regularly cleaned. Although solids accumulation will be spread across a larger area that will make cleaning more difficult, cleaning the tanks often should prevent degradation of solids and subsequent nutrient releases.
5. Sludge can be land applied in a number of ways…develop a disposal plan based on the solids accumulations and land requirements estimated in [the Boardman et al. 1998] report.
6. Composting of the sludge should be studied to determine if there may be an economic benefit.
7. Erosion control should also be considered to improve water quality and fish production.
8. Avoid flow diversion unless under flooding conditions. All effluents should be directed through the proposed treatment system.
9. A high energy nutrient dense feed should be used to minimize solids input to the systems.
10. During basin cleanings, flows should be diverted to settling basins in order to prevent solids spikes from entering other basins or receiving waters.
11. Detailed records of fish densities, growth, feed input and FCRs [feed conversation ratios] should be kept and updated on a bi-weekly basis.
12. In manual feed systems, FCRs should be kept as low as possible to minimize wasted feed. Frequent monitoring of FCRs is necessary to properly adjust feeding rates.
13. The daily allowances of feed for each basin should be rationed in small amounts throughout the day.
14. The effectiveness and maintenance of demand feeders should be checked on a regular basis in order to avoid periods of underfeeding.
15. The use of ultrasound to control feeding should be investigated. This feeding practice is used to feed fish to satiation and maintain low FCRs.
16. Fine particulates should be removed from feed before it enters the raceways. These fines contribute to higher FCRs and can adversely affect fish health.

13.2.2 Nonpoint Source Reductions

The impaired streams receive significant sediment loads from nonpoint sources wherever the stream banks are eroded and/or livestock have direct access to the stream. Therefore, improvement of stream riparian areas for some streams is essential for benthic restoration. Specific implementation plans for nonpoint source reductions should be developed for each site. Cost-share monies are available through the federal 319 program and the Virginia Water Quality Improvement fund. The following Best Management Practices (BMPs) are recommended to control nonpoint source pollution.

13.2.2.1 Keep livestock away from streams

Several of the impaired segments flow through pastures where livestock have direct access to the stream. Livestock trample vegetation and make stream banks unstable. Fences should be installed along these stream segments to prevent livestock access to the stream and consequently prevent the direct disposition of manure (high in organic matter). Fencing will also facilitate vegetative growth along eroded stream banks, which will slow sediment transport to the stream.

13.2.2.2 Establish canopy cover and buffer strips

Vegetative buffer strips of shrubs and trees should be planted along the impaired segments and along the section upstream of the trout facility on Pheasanty Run.   Buffer strips will slow sediment movement into the stream. In addition to providing stream bank stabilization, riparian shrubs and trees will also shade the stream and provide food for benthic macroinvertebrates in the form of fallen leaves.

13.3 FUTURE DIRECTION

Because of the uncertainties in the effectiveness of the point source control measures, experiments at the trout farms should be designed, and targeted monitoring should be part of the experiment design. Studies using redesigned sediment traps are recommended. Different schedules and practices of sediment trap and settling basin cleaning should be monitored for organic solids input into the stream and the effects on the streambed. In this way, the frequency of cleaning and cleaning strategies will be better defined.

Pollutant loads in aquaculture effluent are proportional to the amount of feed put into the system. Some European countries use feed types and amounts instead of effluent concentrations to monitor the input of solids and other pollutants to streams. A study using stable isotopes of carbon ($^{13}C/^{12}C$) and nitrogen ($^{15}N/^{14}N$) could be incorporated into future research to address questions about the amount of solids generated from a given amount of feed and the proportion of solids in the effluent from unconsumed feed versus fecal matter.

There is also a need to conduct a review of the appropriate and attainable uses for the listed streams in order to set appropriate targets for benthic assessments**.**

14 PUBLIC PARTICPATION

Two public meetings were held so that local stakeholders, DEQ and DCR personnel, and the TMDL team could discuss openly and as a group the TMDL goals, challenges, and means by which to meet the goals. Both public meetings were held in Harrisonburg at the Valley Regional DEQ office, and approximately 20 people attended each meeting. The first public meeting was held on June 12, 2001, and the second meeting was held on March 27, 2002. At the first meeting, the proposed TMDL approach was explained, and input was received from the attendees. At the second meeting, the TMDL study results were explained and proposed TMDLs were presented. At both meetings, stakeholders asked questions, which were addressed.

A survey questionnaire was mailed to the manager or owner of each of the trout facilities located on the impaired streams (Appendix J). The survey asked about the spring flow and impaired segment, and about the facility's activities (including feeding and solids removal) as well as trout production. Responses from facility personnel were used in the decision making process and in the development of the TMDL report.

REFERENCES

Alabaster, J. S. 1982. Survey of Fish-Farm Effluents in Some EIFAC Countries. EIFAC Tech. Paper 41:5-20.

Boardman, G. D., V. Maillard, J. Nyland, G. J. Flick, and G. S. Libey. 1998. *The Characterization, Treatment and Improvement of Aquacultural Effluents.* Departments of Civil and Environmental Engineering, Food Science and Technology, and Fisheries and Wildlife Sciences. Virginia Polytechnic Institute and State University. Blacksburg, VA. 123 pp.

Bolgiano, R. 1995a. Department of Environmental Quality Memorandum: Cockran Spring Branch - Benthic Survey, QL 95-004.

Bolgiano, R. 1995b. Department of Environmental Quality Memorandum: Lacey Spring Branch - Benthic Survey, QL 95-003.

Bolgiano, R. 1995c. Department of Environmental Quality Memorandum: Coursey Springs Branch - Benthic Survey, QL 95-054.

Bolgiano, R. 1995d. Department of Environmental Quality Memorandum: Montebello - Benthic Survey, QL 95-006.

Bolgiano, R. 1996a. Department of Environmental Quality Memorandum: Orndorff - Benthic Survey, QL 96-005.

Bolgiano, R. 1996b. Department of Environmental Quality Memorandum: Casta Line - Benthic Survey, QL 96-003.

Brown, C. A. 1996. Macroinvertebrate Community Patterns in Relation to Physico-chemical Parameters Measured at Two Land-based Trout Farms Affecting Streams in South-western Cape, South Africa. *Arch. Hydrobiol.* 138: 57-76.

Camargo, J. A. 1992. Temporal and Spatial Variations in Dominance, Diversity and Biotic Indices Along a Limestone Stream Receiving a Trout Farm Effluent. *Water, Air, and Soil Pollution* 63: 343-359.

Camargo, J. A. 1994. The Importance of Biological Monitoring for the Ecological Risk Assessment of Freshwater Pollution: A Case Study. *Environment International* 20: 229-238.

Davies, P.E. and M. Nelson. 1994. Relationships between Riparian Buffer Widths and the Effects of Logging on Stream Habitat, Invertebrate Community Composition and Fish Abundance. *Aust. J. Mar. Freshwater Res*. 45: 1289-1305.

DEQ (Water Permits Manager). 1997a. Reissuance of VPDES Permit No. VA0006491. Valley Regional Office Memorandum, May 24, 1997.

DEQ. 1997b. VPDES Permit Program Statement of Basis. Permit No. VA0006491.

DEQ. 1997c. VPDES Permit Program Statement of Basis. Permit No. VA0006505.

DEQ. 1998a. General Permit for Concentrated Aquatic Animal Production Facilities. 9 VAC 25-195-50. http://www.deq.state.va.us/regulations/xwaterregs.html (September 6, 2000).

DEQ. 1998b. *Virginia 303(d) Total Maximum Daily Load Priority List and Report*. Department of Environmental Quality and Department of Conservation and Recreation. Richmond, Virginia. 259 pp.

DGIF (Virginia Department of Game and Inland Fisheries). 2001. Fish for Stocking…Where do they come from? http://www.dgif.state.va.us/fishing/Fishing_Guide/fish_4_stocking.html (January 26, 2001).

Dillaha, T. A., J. H. Sherrard, D. Lee, V. O. Shanholtz, S. Mostaghimi, and W. L. Magette. 1986. *Use of Vegetative Filter Strips to Minimize Sediment and Phosphorus Losses from Feedlots: Phase I. Experimental Plot Studies*. Virginia Water Resources Research Center. Bulletin 151. Virginia Polytechnic Institute and State University. Blacksburg, VA. 68 pp.

EPA. 1991. *Guidance for Water Quality-based Decisions: The TMDL Process.* U.S. Environmental Protection Agency, Office of Water, Washington, DC. EPA 440/4-91-001. April 1991.

EPA. 1997. *Volunteer Stream Monitoring: A Methods Manual*. U.S. Environmental Protection Agency, Office of Water, Washington, DC. EPA 841-B-97-003.

EPA. 1999. *1999 Update of Ambient Water Quality Criteria for Ammonia*. U.S. Environmental Protection Agency, Office of Water, Washington, DC. EPA 822-R-014. September 1999.

EPA. 2000. *Stressor Identification Guidance Document*. U.S. Environmental Protection Agency, Office of Water, Washington, DC. EPA 822/B-00/025. December 2000.

Foth, H. D. 1990. *Fundamentals of Soil Science*. Eighth Edition. John Wiley and Sons, New York, NY.

Frondorf, L. 2001. *An Investigation of the Relationship Between Stream Benthic Macroinvertebrate Assemblage Conditions and Their Stressors*. Unpublished M.S. Thesis. Virginia Polytechnic Institute and State University. Blacksburg, VA. 169 pp.

Greenfield, J. M. 2002. Sediment Tool: A Simple Method for Erosion and Sediment Delivery Estimation. (Contact: J. Greenfield [Greenfield.jim@epa.gov]), U. S. Environmental Protection Agency Region 4. Atlanta, GA. http://www.wef.org/pdffiles/TMDL/Greenfield.pdf. (April 8, 2002).

Heinonen, P. 1984. Early Warning of Eutrophication in Rivers by Analysis of Periphyton Cholrophyll *a*. p 45-52. In D. Pascoe and R. W. Edwards (eds.), *Freshwater Biological Monitoring*. Pergamon Press. Oxford. 167 pp.

Hellawell, J. M. 1986. *Biological Indicators of Freshwater Pollution and Environmental Management*. Elsevier Applied Science Publishers. London.

Jones, C. R. 2001. *Determination of Environmental Stressors Influencing Benthic Invertebrate Community Structure: A Multivariate Statistical Approach*. Draft Final Report Submitted to the Virginia Water Resources Research Center (Contact: R. Christian Jones [rcjones@gmu.edu]). George Mason University. Fairfax, VA. 87 pp.

IDEQ (Idaho Department of Environmental Quality). 1998. *Idaho Waste Management Guidelines for Aquaculture Operations*. Idaho Department of Health and Welfare. Division of Environmental Quality. Twin Falls, ID.

Kendra, W. 1991. Quality of Salmonid Hatchery Effluents During a Summer Low-flow Season. *Transactions of the American Fisheries Society* 120: 43-51.

Kondratieff, P. F. and G. M. Simmons, Jr. 1982. Nutrient Retention and Macroinvertebrate Community Structure in a Small Stream Receiving Sewage Effluent. *Arch. Hydrobiol.* 94(1): 83-98.

Loch, D. D., J. L. West, and D. G. Perlmutter.   1996. The Effect of Trout Farm Effluent on the Taxa Richness of Benthic Macroinvertebrates. *Aquaculture* 147: 37-55.

Massik, Z. and M. J. Costello. 1995. Bioavailability of Phosphorus in Fish Farm Effluents to Freshwater Phytoplankton. *Aquaculture Research* 26: 607-616.

Metcalf and Eddy, Inc.   1991. *Wastewater Engineering: Treatment, Disposal, Reuse.* Third Edition. McGraw-Hill. New York, NY.

Novotny, V. and H. Olem. 1994. *Water Quality Prevention, Identification, and Management of Diffuse Pollution.* Van Nostrand Reinhold. New York, NY.

Selong, J. H. and L. A. Helfrich. 1998. Impacts of Trout Culture Effluent on Water Quality and Biotic Communities in Virginia Headwater Streams. *The Progressive Fish-Culturist* 60: 247-262.

Summerfelt, S. T. 1998. An Integrated Approach to Aquaculture Waste Management in Flowing Water Systems. *Second International Conference on Recirculating Aquaculture*. Roanoke, VA.

Tufford, D. L., H. N. McKellar, Jr., and J. R. Hussey. 1998. In-Stream Nonpoint Source Nutrient Prediction with Land-Use Proximity and Seasonality. *J. Environ. Quality* 27:100-111.

Van Wart, W. 2000a. Department of Environmental Quality. Casta Line (Middlebrook) Benthic Sample Data for August 15, 2000.

Van Wart, W. 2000b. Department of Environmental Quality. Lacey Spring Upstream of Route 81. Benthic Sample Data for August 8, 2000.

Van Wart, W. 2000c. Department of Environmental Quality. Coursey Spring Benthic Sample Data for August 2, 2000.

Van Wart, W. 2000d. Department of Environmental Quality. Casta Line (Craigsville), X-Tributary Byrd Spring Branch, Property Line. Benthic Sample Data for August 15, 2000.

Van Wart, W. 2000e. Department of Environmental Quality. Casta Line (Craigsville), X-Tributary Byrd Spring Branch, Route 684. Benthic Sample Data for August 15, 2000.

Westerman, P. W., J. M. Hinshaw and J. C. Barker. 1993. Trout Manure Characterization and Nitrogen Mineralization Rate. In *Techniques for Modern Aquaculture.* Proceedings of ASAE Aquacultural Engineering Conference, Spokane, WA. June 21-23, 1993. p. 35-43. American Society of Agriculture Engineers Publication 02-93, ASAE. St. Joseph, MI.

Yetman, K. T. 2000. *Stream Corridor Assessment Survey SCA Survey Protocols*. Maryland Department of Natural Resources. Watershed Restoration Division. Chesapeake and Coastal Watershed Services. Annapolis, MD.

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APPENDIX A - Benthic Macroinvertebrate Survey Results

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I. Introduction

The Virginia Water Resources Research Center, in conjunction with the VA Department of Environmental Quality (DEQ), is conducting studies focused on developing appropriate TMDLs for six stream segments that receive trout farm discharges. Four of the facilities are private farms and two are VA Department of Game and Inland Fisheries facilities. The DEQ conducted past benthic surveys of the receiving streams using procedures from EPA's Rapid Bioassessment Protocol II (RBP II). Those studies resulted in the stream segments being declared as impaired for supporting aquatic life, thereby requiring the streams to be included in the Year 1998 303(d) impaired waters list. It was recommended that a more in-depth benthic study be conducted at each of these sites to provide additional data for further evaluation of the "impaired" status of the streams. The report that follows details the methods and findings of the additional benthic studies.

II. Sampling Sites

1. Orndorff Spring Branch: Located in Shenandoah County in the Shenandoah River basin. The headwater of this first-order stream is a perennial spring. The stream segment sampled began just below a trout farm discharge and continued 0.15 miles downsteam to the confluence with Cedar Creek.

2. Montebello Spring Branch: Located in Nelson County in the James River basin near Montebello, VA. The stream segment sampled began at a fish cultural station discharge and continued downstream 0.02 miles to the confluence with Mill Creek.

3. Cockran Spring Branch: Located in Augusta County in the Shenandoah River basin near Middlebrook, VA. The stream segment sampled began at a trout farm discharge and continued downstream for 0.8 miles to the confluence with the Middle River.

4. Wallace Mill Stream: Located in Augusta County in the James River Basin near Craigsville, VA. The stream segment sampled began at a trout farm discharge and continued downstream to the confluence with Byrd Spring Creek. Sampling was conducted at two locations on this segment:

    A. Wallace Mill Stream A: located immediately below the discharge from the trout farm.

    B. Wallace Mill Stream B: located near the confluence with Byrd Spring Creek.

5. Lacey Spring Branch: Located in Rockingham County in the Shenandoah River basin. The stream segment sampled began at a trout farm discharge and continued downstream for 0.2 miles to the confluence with Smith Creek.

6. Pheasanty Run (Coursey Springs): Located in Bath County in the James River basin near Williamsville, VA. The headwater of this first-order stream is Coursey Springs, a large perennial spring. The stream segment sampled began at the discharge from a fish cultural station and continued downstream to the confluence with the Cowpasture River.

Reference stations were chosen and sampled by DEQ personnel concurrently with the above stations:

7. Ingleside Spring Branch: Located in Rockbridge County in the James River basin. This site served as the reference station for Orndorff Spring Branch, Montebello Spring Branch, Cockran Spring Branch and both sites on Wallace Mill Stream.

8. Mount Solon Spring Branch: Located in Augusta County in the Shenandoah River basin. This site served as the reference site for Lacey Spring Branch and Pheasanty Run.

One additional site was originally sampled because it was thought that it might be able to serve as a good reference site for spring-fed streams. It was not used as a reference site on recommendation of DEQ personnel. Data on the site are included for completeness in reporting of the findings for all samples collected.

9. Spring Creek Spring: Located in Rockingham County in the Shenandoah River basin. Segment sampled was from the private bridge below the spring to the confluence with Spring Creek.

A tenth site was sampled after the above nine sites were sampled, with the intent of determining if it might serve as a reference site for one or more of the original sites.

10. Glover Run Tributary: Located in Augusta county in the Little Calfpasture River basin (James River basin). It is located just south of Wallace Mill Stream near Craigsville, VA.

III. Methods

DEQ personnel (Valley Regional Office) conducted quantitative benthic sampling in March-April 2001 at all sampling sites, except that Glover Run Tributary was sampled in November. Samples were taken with a Hess Stream Bottom Sampler (0.08 m^2), preserved in isopropyl alcohol and sent for processing to the Aquatic Ecology Lab in the Department of Biology at Virginia Commonwealth University. Five replicate Hess samples were collected at each site.

In the laboratory all macroinvertebrates were removed from the debris of each sample. As part of the requested protocol for this study, macroinvertebrates were then identified to the genus level. Family level identification had been used for the original benthic surveys, following RBP II protocols. It was hoped that the information provided by genus level identifications in this study might provide additional insights into the condition of the streams.

A number of metrics describing aspects of the taxonomic composition and structure of the macroinvertebrate communities at each site were calculated as means of the five replicate samples:

1. Density – mean number of individuals per square meter of stream bottom.

2. Taxa richness – mean number of taxa collected per site.

3. EPT richness – mean number of taxa in the insect orders Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (stoneflies).

4. Percent EPT taxa (% EPT) – mean of the number of EPT individuals divided by the total number of macroinvertebrate individuals in a sample (expressed as a percent).

5. Percent Scraper taxa (% SC) – mean of the number of individuals in the scraper functional feeding group divided by the total number of individuals in a sample (expressed as a percent).

6. Percent Shredder taxa (% SH) – mean of the number of individuals in the shredder functional feeding group divided by the total number of individuals in a sample (expressed as a percent).

7. Modified Hilsenhoff Biotic Index (HBI) – provides a quantitative assessment of the tolerance of the invertebrate taxa at a site to general water and habitat quality degradation, weighted by the relative abundance of each taxon.

These seven metrics, calculated for each site, were then tested to determine if significant differences existed in the metric values between study and reference sites. Because the data were not normally distributed, a Mann-Whitney U Test was used as the statistical test. Alpha was set at 0.05 for all statistical tests. Though the relative abundance of all functional feeding groups was tested, only the results of the Mann-Whitney U Tests for scrapers and shredders are reported here. These two tend to be the feeding groups that best reflect changes in water and habitat quality. No additional insights on the condition of the streams were provided by the data for the other feeding groups.

DEQ personnel collected some water quality and habitat data at the sites concurrent with the benthic sampling (Valley Regional Office). Alkalinity, pH, conductivity and pebble count data were considered the most relevant data to examine to provide an indication of the similarity between the reference sites and the study streams.

IV. Results

Ingleside Spring Branch (Reference Site)

The benthic community at Ingleside Spring Branch was composed of a variety of species, 23 taxa occurring in the five replicate samples combined and five of those being EPT taxa. Scrapers dominated the community because of the abundance of the snail *Somatogyrus* (Table A.1), by far the most abundant taxon at the site. The mean HBI value of 6.2 reflected a community composed of primarily moderately tolerant taxa. Few taxa with HBI values indicative of highly tolerant species were common at the site, whereas a number of taxa that have low HBI values indicating intolerant species were common.

Mount Solon Spring (Reference Site)

The benthic community at Mount Solon Spring was composed of slightly fewer taxa than were found at Ingleside, 19 taxa occurring in the samples. Only three of the taxa were EPT taxa. Isopods were the most common taxon, but overall no one or even a few taxa dominated the community in terms of abundance. Four taxa of snails were found; the two taxa of pleurocerid snails were fairly common whereas the other two taxa occurred only in one sample each. The abundance of isopods made the relative abundance of shredders the highest of the functional feeding groups (Table A.1). The HBI value of 7.3 reflected a community composed of moderately tolerant to tolerant taxa.

Orndorff Spring Branch

The benthic community at Orndorff Spring Branch was significantly different from its reference site (Ingleside) in five of the seven tested metrics (Table A.2). Although mean density was over 45,000 individuals/m^2 at this site compared to about 25,000 individuals/m^2 at the reference site (Table A.1), there was no statistically significant difference in this metric between the two sites. The two EPT metrics were significantly different from the reference site, reflecting no EPT taxa occurring in the samples from this site. Oligochaetes, a planorbid snail, isopods and planaria dominated the benthic community. All three of these taxa are quite tolerant species, as are several other taxa common at the site. Community composition was similar to that found by previous DEQ benthic surveys except that chironomids were not as important a component of the community as in the DEQ surveys. The mean HBI value of 8.1 was significantly greater than at the reference site, indicating a shift in community composition to more tolerant species. The percent abundance of scrapers and shredders were significantly different from the reference site, caused by the changes in species composition to the more tolerant species.

Montebello Spring Branch

The benthic community at Montebello Spring Branch was significantly different from its reference site (Ingleside) in three of the seven tested metrics (Table A.2). Only the scraper, shredder and biotic index metrics were significantly different from the reference site, together reflecting changes in the species composition of the benthic community here compared to the reference site. Isopods, oligochaetes and a physid snail were the dominant taxa. Isopods and oligochaetes were the dominant organisms in previous DEQ benthic surveys. These and most of the other common taxa are all very tolerant taxa, resulting in a mean HBI value of 8.4 compared to 6.2 at the reference site. Thus, although only three of the metrics calculated for this site were significantly different from the reference site, the other three metrics do reflect a change in the species composition to one tolerant of water and habitat degradation.

Cockran Spring Branch

The benthic community at Cockran Spring Branch was significantly different from its reference site (Ingleside) in all metrics except density of organisms (Table A.2). Only five taxa occurred in the samples and all but one of them were highly tolerant taxa. No EPT taxa occurred in the samples from this site. The mean HBI value of 9.2 was the highest value for all of the sites (Table A.1). The community was dominated by isopods and oligochaetes, similar to findings from previous DEQ benthic surveys.

Wallace Mill Stream

The two assessed sites on Wallace Mill Stream were quite different from each other. The site at river mile 0.64 (Wallace Mill A) was significantly different from its reference site (Ingleside) in all metrics but density. Only eight taxa occurred in the samples from this site, none of which was an EPT taxon. The dominant taxa were isopods, oligochaetes and planarians, reflecting poor water and habitat quality. Isopods also were the dominant taxa in the DEQ benthic surveys taken in 2000. The mean HBI value of 7.4 reflected a community composed of moderately tolerant to tolerant taxa.

The benthic community at the downstream site on Wallace Mill Stream (B) indicated somewhat better conditions in the stream. Only two metrics, the percent scrapers and percent shredders, were significantly different from the reference site. Taxa and EPT richness were quite similar to the reference site, with four EPT taxa occurring in the samples. Although oligochaetes and isopods again were the most common taxa, they did not dominate to the extent that they did upstream. Despite the HBI value (8.7) being higher for the downstream site, the other metrics together show this site to have a higher quality than the upstream site because no one metric decides the "quality" of a site, but rather the overall suite of metrics provides the information to make the decision.

Lacey Spring Branch

The benthic community at Lacey Spring Branch was significantly different from its reference site (Mount Solon) in only one metric. Only eight taxa occurred in the samples from this site, mean taxa richness being the only significantly different metric. Only one EPT taxon was found. Mean density was nearly three times higher than at the reference site, but high variability among replicates led to there being no statistically significant difference with the reference site for this metric. The benthic community was dominated in numbers by isopods, oligochaetes and hydrobiid snails, similar to the reference site; however, there were fewer rarer taxa here than at the reference site, leading to the difference in mean taxa richness. Community composition was similar to that found during previous DEQ benthic surveys. The HBI value of 7.3 reflected a community composed of moderately tolerant to tolerant taxa.

Pheasanty Run

The benthic community at Pheasanty Run was significantly different from its reference site (Mount Solon) in four of the seven metrics. This was the only site where the density of organisms was significantly different, being about four times greater than at the reference site (Table A.1). Only one EPT taxon occurred in the samples and the percent EPT taxa was significantly different from the reference site. The community was dominated by tolerant taxa, especially isopods, oligochaetes and planarians, similar to previous DEQ benthic surveys. No snails were found in the samples, the lack of these scrapers leading to the percent scraper metric being significantly different from the reference site. The mean HBI value for the site was 8.8, reflecting the dominance of the tolerant taxa.

Spring Creek Spring

No statistical comparisons were made for the benthic community metrics from Spring Creek Spring since this site was sampled only as a possible reference site. All of the metrics for this site reflected moderate to high water and habitat quality. It had low density as well as highest taxa richness and EPT richness. Ten EPT taxa were found in the samples from this site. The community was numerically dominated by ephemerellid mayflies, bracycentrid caddisflies and the filter-feeding chironomid *Rheotanytarsus*. Tolerant taxa were uncommon, leading to a very low mean HBI value of 2.2.

Glover Run Tributary

No statistical comparisons were made for the benthic community metrics from Glover Run Tributary since this site was sampled only as a possible reference site. All of the metrics for this site reflected high water quality. Macroinvertebrate density was much lower at this site than at any of the others. Taxa richness (19 taxa) and EPT richness (8) were far higher than at the other sites. The community was numerically dominated by snails and elmid beetles. Also, the percentage of individuals that were EPT taxa was much higher here than at the other sites. Species in the scraper functional feeding group dominated the site because of the abundance of the snails. The mean HBI value of 4.8 was low, reflecting the presence of a high number of intolerant taxa.

Physicochemical Data

In comparing the streams considered as potential reference streams, alkalinity and conductivity were higher, pH was lower and the sediment was composed of far more fine particles (< 2 mm) at Ingleside Spring Branch than at Mount Solon Spring (Table A.3). Alkalinity and conductivity were far lower at Spring Branch Spring than at the other potential reference streams; its sediment was similar to that of Ingleside, with a predominance of fine particles. Glover Run Tributary had an alkalinity and conductivity intermediate to that at Ingleside and Mount Solon, a pH similar to that at Mount Solon and higher than at the other sites. The substrate sediment at Glover Run Tributary was similar to that at Mount Solon except that bedrock rather than particles in the 32-128 mm size range was predominant.

Following is a comparison of the chemical and sediment data from the receiving streams to that of their assigned reference stream:

- Orndorff Spring Branch was very similar in chemical and sediment characteristics to Ingleside Spring Branch, its assigned reference stream.

- Montebello Spring Branch had chemical and sediment characteristics quite different from Ingleside, its assigned reference stream, alkalinity and conductivity being much lower than at Ingleside. Its characteristics were more similar to Mount Solon Spring.

- Cockran Spring Branch was similar in chemical characteristics to Ingleside, its assigned reference stream, but Ingleside had far more fine sediments (< 2 mm) than did Cockran.

- Wallace Mill Stream had chemical and sediment characteristics closer to Mount Solon Spring than to Ingleside, its assigned reference stream.

- Lacey Spring Branch had much higher alkalinity and conductivity than any of the other streams. Its chemical and sediment characteristics were closer to Ingleside than to Mount Solon Spring, its assigned reference stream.

- Pheasanty Run had chemical and sediment characteristics similar to Mount Solon Spring, its assigned reference stream.

V. Discussion

All of the stream segments that were located below trout farm discharges showed some signs of enrichment. This was indicated primarily by a greater numerical dominance of taxa such as oligochaetes, isopods and planaria, taxa that are tolerant of poor water and habitat quality. Though these taxa are expected to occur in spring-fed, headwater streams, their relative abundance typically was greater than expected for unenriched streams. The high HBI values, which were statistically greater than at the reference streams for all but one site, further indicates the change in either species composition or the relative abundance toward tolerant taxa.

The statistical analysis of the density data showed only one site with a density significantly different from its reference site. High variability in the density of replicate samples for some sites may have caused the tests to show no statistically significant difference. Overall there was no clear trend of increased density at most sites, increased density being expected under enriched conditions.

The benthic community in Orndorff Spring Branch was clearly different from that expected in a reference stream. It was composed for more oligochaetes and planaria than would occur in a reference stream and the species of snails expected in a reference stream likely would not be *Physella* and *Gyraulus*, which are quite tolerant of enriched conditions. The total lack of EPT taxa also is not expected, although the substrate was not particularly conducive to supporting many EPT taxa.

The benthic community in Montebello Spring Branch also was different from that expected in a reference stream. Oligochaetes and isopods were numerically very dominant; those taxa would occur in a reference stream but not to the extent found in this stream. Though no EPT taxa occurred in the stream, the substrate was not conducive to supporting those taxa.

Cockran Spring Branch was clearly impaired. Only five taxa occurred in the samples from this site, and the three taxa that were numerically dominant are all very tolerant taxa. Far greater species richness, EPT richness and different abundance patterns of functional feeding groups would be expected if the stream were not impaired.

Wallace Mill Stream was impaired immediately below the discharge as indicated by the low species richness, total lack of EPT taxa and high relative abundance of oligochaetes and isopods. The data suggest that the stream quality was improved at the downstream sampling site, as indicated by the higher richness, the presence of EPT taxa and the presence of tolerant taxa in numbers that were not as dominant as they were upstream.

Lacey Spring Branch may be impaired based on the low species richness and only one EPT taxon occurring in the samples.

Pheasanty Run may be impaired based on the much higher density of macroinvertebrates than expected, the extent of the numerical dominance of tolerant taxa and the occurrence of only one EPT taxon in the samples.

The benthic communities found in Spring Creek Spring and Glover Run Tributary suggest that these were the highest quality streams of those sampled. Spring Creek Spring had high species richness, high EPT richness with 10 taxa being found, an appropriate representation of all functional feeding groups and the presence of tolerant taxa in numbers that were not highly dominant. The lack of isopods and planaria in the samples from this stream likely is a result of the chemical characteristics of the stream, its low alkalinity and conductivity being unlike that of the reference spring streams where those two taxa do occur. Glover Run Tributary had a benthic community unlike any of the other sites, having a very high taxa richness, far more EPT taxa than any of the other sites, and a greater dominance of snails than other sites except for Ingleside Spring Branch.

A question can be raised concerning the adequacy of the assigned reference sites. From the chemical and sediment data provided, there is a question about the appropriateness of Ingleside Spring Branch as the benthic reference stream for Montebello Spring Branch and Wallace Mill Stream and possibly also for Cockran Spring Branch. There also is the question of the appropriateness of Mount Solon Spring as the benthic reference stream for Lacey Spring Branch.

Spring Creek Spring was sampled as a possible replacement of Mount Solon Spring Branch as the benthic reference stream for Lacey Spring Branch. However, the alkalinity and conductivity of Spring Creek spring were substantially lower compared to that of Lacey Spring Branch. The chemical characteristics of Spring Creek Spring eliminated it as a reference site for this stream since its low alkalinity and conductivity are unlike "normal" spring waters in the area. In regards to chemical characteristics, Spring Creek Spring was more similar to Montebello Spring Branch, but its different flow classification (large) and sediment composition of the substrate (71 percent being less than 2 mm) make it unsuitable as a reference for Montebello Spring Branch (a small flow stream with none of its substrate sediment composition being less than 2 mm) (Table A.3).

A stakeholder suggested using Glover Run Tributary as a possible reference stream for Wallace Mill Stream (to replace Ingleside Spring Branch). Although Glover Run has similar chemical characteristics to Wallace Mill Stream, the benthic community was characteristic of a non-limestone mountain spring. Glover Run also had substrate sediment characteristics that were very unlike Wallace Mill Stream (or any other stream in the study)—a predominance of bedrock and very large particles. Given the importance of sediment particle size in determining macroinvertebrate community composition and structure, Glover Run therefore was not used as a reference site for any stream.

Mill Creek, the benthic reference stream used to initially list Montebello Spring Branch as impaired, was not sampled. Instead resources were spent in an attempt to locate a different reference stream. The most likely potential reference identified for Montebello Spring Branch was Cold Spring Run. According to the DEQ aquatic biologist, this stream had too much surface flow to be a good spring reference so benthic samples were not collected. Because the past DEQ data using RBPII provided the same general results as the TMDL benthic sampling for all other sites, the benthic community of Mill Creek should be adequately described by the earlier DEQ data.

The other two reference streams used in the TMDL report (Ingleside Spring Branch and Mount Solon Spring Branch) had taxa richness values of 9.8 (Table A.1). More taxa were observed in Ingleside Spring Branch (23) compared to in Mount Solon Spring Brnach (19). The density of organisms was also higher in Ingleside Spring Branch. Only five of the taxa were EPT taxa in Ingleside Spring Branch, while only three of the taxa were EPT taxa in Mount Solon Spring Branch. Scrappers dominated in Ingleside Spring Branch owing to the abundance of the snail *Somatogyrus*, while shredders dominated in Mount Solon Spring Branch owing to the abundance of isopods. Ingleside Spring Branch received a lower HBI value (6.2) compared to Mount Solon (7.3), indicating more intolerant species in Ingleside Spring Branch.

Table A.1. Mean metric values for reference and receiving streams. 1 SE in parentheses. IS = Ingleside Spring Branch; MS = Montebello Spring Branch; OS = Orndorff Spring Branch; CS = Cockran Spring Branch; WM-A and WM-B =Wallace Mill Stream A and B; MSS = Mount Solon Spring Branch; LS = Lacey Spring Branch; PR = Pheasanty Run; SC = Spring Creek Spring; GL = Glover Run Tributary.

	IS	MS	OS	CS	WM-A	WM-B	MSS	LS	PR	SC	GL
Density	25,409	25,879	45,616	19,861	34,419	17,042	10,146	27,740	40,614	5,530	2,360
(individuals/m^2)	(8,935)	(6,239)	(8,969)	(6,225)	(13,053)	(4,069)	(3,078)	(15,258)	(4,292)	(1,518)	(643)
Taxa Richness	9.8	9.0	8.2	3.2	4.8	10.6	9.8	5.0	6.6	12.0	19
	(2.5)	(0.3)	(1.1)	(0.4)	(0.4)	(1.4)	(1.1)	(0.7)	(0.7)	(1.4)	(1.1)
# EPT Taxa	1.4	1.2	0.0	0.0	0.0	1.8	1.4	0.6	0.2	5.0	8
	(0.9)	(0.2)	(0.0)	(0.0)	(0.0)	(0.7)	(0.5)	(0.2)	(0.2)	(0.8)	(1.3)
% EPT	2.0	1.8	0.0	0.0	0.0	3.2	3.3	5.2	0.1	0.9	23.3
	(1.0)	(0.5)	(0.0)	(0.0)	(0.0)	(2.2)	(1.3)	(2.5)	(0.1)	(0.1)	(4.4)
% SC	86	7	13	0	0	<1	15	28	<1	1	61.8
	(5)	(3)	(4)	(0)	(0)	(<1)	(7)	(13)	(<1)	(<1)	(5.0)
% SH	3	50	14	84	45	49	55	50	66	14	7.2
	(1)	(4)	(5)	(4)	(8)	(4)	(8)	(15)	(16)	(8)	(2.5)
HBI	6.2	8.4	8.1	9.2	7.4	8.7	7.3	7.8	8.8	2.2	4.8
	(0.1)	(0.1)	(<0.1)	(0.1)	(0.4)	(0.1)	(0.6)	(0.2)	(0.2)	(0.2)	(0.3)

Table A.2. Results of Mann-Whitney U Test testing for differences in metric values between reference and receiving streams. + indicates a statistically significant difference at $p \leq 0.05$. ORN = Orndorff Spring Branch; MONT = Montebello Spring Branch; COCKR = Cockran Spring Branch; WM–A and WM-B are Wallace Mill Stream A and B; LACEY = Lacey Spring Branch; PHEAS = Pheasanty Run.

	ORN	MONT	COCKR	WM-A	WM-B	LACEY	PHEAS
Density	-	-	-	-	-	-	+
Taxa richness	-	-	+	+	-	+	-
EPT richness	+	-	+	+	-	-	-
% EPT	+	-	+	+	-	-	+
% Scrapers	+	+	+	+	+	-	+
% Shredders	+	+	+	+	+	-	-
HBI	+	+	+	+	-	-	+

Table A.3. Chemical and sediment data for reference and receiving streams.

	Alkalinity (mg/L)	pH	Conductivity (μS/cm)	Sediment (% composition) <2	2-8	8-32	32-128	>128mm (+Bedrock)
Ingleside	134	7.6	215	36	5	34	23	2
Orndorff	137	7.6	209	25	6	24	39	6
Montebello	12	7.3	20	0	7	47	42	4
Cockran	161	7.8	205	8	16	63	14	2
Wallace Mill A	86	8.0	152	4	6	36	45	10
Wallace Mill B	80	8.3	150	10	8	50	32	1
Mount Solon	58	8.0	111	10	14	18	48	9
Lacey	261	7.2	462	49	8	6	22	17
Pheasanty	65	8.0	120	8	12	36	14	3
Spring Creek Spring	22	7.6	45	71	11	10	9	0
Glover Run Trib.	103	8.1	161	14	3	13	19	51

Ingleside Spring Branch
1-May-01
Macroinvertebrate density (individuals per m^2) in each replicate sample.

			XXF1A	XXF1B	XXF1C	XXF1D	XXF1E
Turbellaria	Planariidae	*Dugesia*	47	0	0	0	0
Annelida	Oligochaetae		419	0	186	558	70
Hydracarina			0	0	0	279	70
Ephemeroptera	Baetidae	*Baetis*	47	0	0	0	140
Ephemeroptera	Ephemerellidae	*Ephemerella*	47	372	186	0	0
Ephemeroptera	Heptageniidae	*Stenonema*	140	0	0	0	0
Trichoptera	Brachycentridae	*Micrasema*	47	0	0	0	0
Trichoptera	Glossosomatidae	*Glossosoma*	140	0	0	0	0
Coleoptera	Elmidae	*Dubiraphia*	47	0	0	0	0
Coleoptera	Elmidae	*Macronychus*	0	0	372	0	70
Coleoptera	Elmidae	*Oulimnius*	698	3349	0	0	0
Diptera	Stratomyidae		47	0	0	0	0
Diptera	Diamesini	*Pagastia*	0	372	0	0	0
Diptera	Tanypodinae	*Conchapelopia*	0	0	0	0	81
Diptera	Orthocladiinae	*Cricotopus*	279	1116	0	558	477
Diptera	Orthocladiinae	*Heterotrissocladius*	0	0	0	0	81
Diptera	Orthocladiinae	*Orthocladius*	140	0	0	0	151
Diptera	Orthocladiinae	*Eukiefferiella*	140	372	0	558	953
Diptera	Tanytarsini	*Tanytarsus*	47	0	0	558	81
Diptera	Tipulidae	*Antocha*	47	0	0	279	70
Diptera	Tipulidae	*Pilaria*	47	0	0	0	0
Bivalvia	Sphaeriidae	*Pisidium*	47	0	372	0	70
Gastropoda	Hydrobiidae	*Somatogyrus*	4651	50233	27035	25674	5233
Total			7070	55814	28151	28465	7547

Cockran Spring Branch
10-May-01
Macroinvertebrate density (individuals per m^2) in each replicate sample.

			XDN1A	XDN1B	XDN1C	XDN1D	XDN1E
Turbellaria	Planariidae	*Dugesia*	140	0	372	1814	0
Annelida	Oligochaetae		1116	1860	1860	1256	1116
Isopoda	Asellidae	*Caecidotea*	9907	5209	13023	18419	41488
Diptera	Orthocladiinae	*Eukiefferiella*	0	0	0	0	186
Bivalvia	Sphaeriidae	*Pisidium*	977	0	0	558	0
Total			12140	7070	15256	22047	42791

Orndorff Spring Branch
7-May-01
Macroinvertebrate density (individuals per m^2) in each replicate sample.

			XOS1A	XOS1B	XOS1C	XOS1D	XOS1E
Turbellaria	Planariidae	*Dugesia*	7535	3349	1488	Sample	4465
Annelida	Oligochaetae		22605	23442	25302	Lost During	26047
Isopoda	Asellidae	*Caecidotea*	1953	558	17116	Processing	3721
Diptera	Diamesini	*Diamesa*	0	279	0		0
Diptera	Diamesini	*Pagastia*	0	0	0		372
Diptera	Orthocladiinae	*Cricotopus*	1395	837	3721		2233
Diptera	Orthocladiinae	*Eukiefferiella*	279	0	3721		0
Diptera	Orthocladiinae	*Orthocladius*	0	0	744		0
Diptera	Orthocladiinae	*Parametriocnemus*	0	0	744		0
Diptera	Chironominae	*Dicrotendipes*	279	0	0		0
Diptera	Tanytarsini	*Tanytarsus*	0	0	744		0
Bivalvia	Sphaeriidae	*Pisidium*	558	0	744		0
Gastropoda	Physidae	*Physa*	279	0	1488		372
Gastropoda	Planorbidae	*Gyraulus*	6698	1535	15628		2233
Total			41581	30000	71442		39442

Montebello Spring Branch
1-May-01
Macroinvertebrate density (individuals per m^2) in each replicate sample.

			XXM1A	XXM1B	XXM1C	XXM1D	XXM1E
Annelida	Oligochaetae		7628	2419	4279	11535	8558
Annelida	Hirudinea	*Batracobdella*	0	0	0	372	0
Isopoda	Asellidae	*Caecidotea*	9860	9674	3442	20465	23070
Hydracarina			0	0	93	0	0
Trichoptera	Hydropsychidae	*Hydropsyche*	558	186	0	0	744
Trichoptera	Rhyacophilidae	*Rhyacophila*	0	0	93	372	372
Diptera	Tanypodinae	*Conchapelopia*	0	186	93	0	0
Diptera	Orthocladiinae	*Cricotopus*	186	0	93	372	0
Diptera	Orthocladiinae	*Eukiefferiella*	744	744	930	2605	1116
Diptera	Orthocladiinae	*Orthocladius*	744	186	279	1488	372
Diptera	Simuliidae		186	0	186	0	372
Diptera	Tipulidae	*Antocha*	0	186	0	0	0
Bivalvia	Sphaeriidae	*Pisidium*	1674	558	0	1488	0
Bivalvia	Sphaeriidae	*Sphaerium*	0	0	93	0	0
Gastropoda	Physidae	*Physa*	372	2977	0	2233	5209
Total			21953	17116	9581	40930	39814

Wallace Mill Stream - A
9-May-01
Macroinvertebrate density (individuals per m^2) in each replicate sample.

			XMO2A	XMO2B	XMO2C	XMO2D	XMO2E
Turbellaria	Planariidae	*Dugesia*	698	1860	837	558	1674
Annelida	Oligochaetae		3628	20465	12558	4837	57488
Annelida	Hirudinea		0	372	0	0	0
Isopoda	Asellidae	*Caecidotea*	6070	11535	6977	15070	24558
Diptera	Orthocladiinae	*Cricotopus*	0	372	0	0	0
Diptera	Orthocladiinae	*Orthocladius*	140	0	279	558	558
Diptera	Orthocladiinae	*Parametriocnemus*	70	0	0	0	0
Diptera	Simuliidae		0	372	0	558	0
Total			10605	34977	20651	21581	84279

Wallce Mill Stream - B
9-May-01
Macroinvertebrate density (individuals per m^2) in each replicate sample.

			XMO1A	XMO1B	XMO1C	XMO1D	XMO1E
Turbellaria	Planariidae	*Dugesia*	0	186	186	0	0
Annelida	Oligochaetae		3070	3349	4651	9488	2372
Isopoda	Asellidae	*Caecidotea*	1023	3535	558	4093	279
Ephemeroptera	Baetidae	*Baetis*	0	744	93	0	0
Plecoptera	Nemouridae	*Amphinemura*	93	186	0	0	140
Plecoptera	Perlodidae	*Isoperla*	0	372	0	0	0
Trichoptera	Hydropsychidae	*Hydropsyche*	0	186	186	0	140
Coleoptera	Elmidae	*Stenelmis*	0	186	0	0	0
Diptera	Diamesini	*Pagastia*	0	0	0	372	0
Diptera	Orthocladiinae	*Cricotopus*	2791	8000	4465	9488	6279
Diptera	Orthocladiinae	*Eukiefferiella*	465	558	0	930	0
Diptera	Orthocladiinae	*Nanocladius*	0	0	279	0	0
Diptera	Orthocladiinae	*Orthocladius*	0	1116	651	558	837
Diptera	Orthocladiinae	*Parametriocnemus*	186	1488	0	0	0
Diptera	Chironominae	*Dicrotendipes*	0	0	279	0	0
Diptera	Tanytarsini	*Rheotanytarsus*	465	1488	279	558	0
Diptera	Simuliidae		372	5581	186	0	419
Diptera	Tabanidae	*Tabanus*	0	0	93	0	0
Diptera	Tipulidae	*Hexatoma*	93	930	0	372	419
Gastropoda	Planorbidae	*Gyraulus*	0	0	93	0	0
Total			8558	27907	12000	25860	10884

Mount Solon Spring Branch
24-Apr-01

Macroinvertebrate density (individuals per m^2) in each replicate sample.

			XMS1A	XMS1B	XMS1C	XMS1D	XMS1E
Turbellaria	Planariidae	*Dugesia*	0	279	1116	465	407
Annelida	Oligochaetae		1116	558	419	186	12
Isopoda	Asellidae	*Caecidotea*	5488	5302	4884	6977	826
Decapoda	Cambaridae		0	0	140	93	0
Ephemeroptera	Baetidae	*Baetis*	0	558	140	186	0
Ephemeroptera	Ephemerellidae	*Ephemerella*	279	558	0	372	0
Trichoptera	Glossosomatidae	*Glossosoma*	0	0	0	93	0
Diptera	Ceratopogonidae	*Probezzia*	279	0	0	93	0
Diptera	Simuliidae		0	1116	558	372	58
Diptera	Orthocladiinae	*Cricotopus*	0	279	0	0	0
Diptera	Orthocladiinae	*Orthocladius*	0	0	0	93	0
Diptera	Tanytarsini	*Rheotanytarsus*	558	3907	279	0	0
Diptera	Tanytarsini	*Tanytarsus*	93	0	0	0	23
Diptera	Tipulidae	*Antocha*	186	279	0	0	12
Bivalvia	Sphaeriidae	*Pisidium*	651	0	0	0	0
Gastropoda	Physidae	*Physa*	186	0	0	0	0
Gastropoda	Pleuroceridae	*Leptoxis*	372	3349	558	93	0
Gastropoda	Pleuroceridae	*Leptoxis*	930	4465	1395	0	0
Gastropoda	Vivparidae	*Campeloma*	0	0	0	93	0
Total			10140	20651	9488	9116	1337

Lacey Spring Branch
23-Mar-01
Macroinvertebrate density (individuals per m^2) in each replicate sample.

			LAC1A	LAC1B	LAC1C	LAC1D	LAC1E
Annelida	Oligochaetae		0	93	1860	2977	5581
Isopoda	Asellidae	*Caecidotea*	21209	4047	7070	558	12279
Trichoptera	Brachycentridae	*Micrasema*	2233	791	744	0	0
Diptera	Orthocladiinae	*Cricotopus*	0	0	372	0	0
Diptera	Orthocladiinae	*Eukiefferiella*	0	47	0	0	0
Diptera	Orthocladiinae	*Parametriocnemus*	372	47	186	0	372
Bivalvia	Sphaeriidae	*Pisidium*	372	0	744	0	0
Gastropoda	Hydrobiidae	*Somatogyrus*	4093	1023	3163	372	68093
Total			28279	6047	14140	3907	86326

Pheasanty Run
3-May-01
Macroinvertebrate density (individuals per m^2) in each replicate sample.

			PTY1A	PTY1B	PTY1C	PTY1D	PTY1E
Turbellaria	Planariidae	*Dugesia*	5209	2233	2233	744	0
Annelida	Oligochaetae		6884	6140	6326	17860	6698
Annelida	Hirudinea		0	0	372	744	558
Annelida	Hirudinea	*Percymoorensis*	0	558	0	0	0
Annelida	Hirudinea	*Placobdella*	0	558	0	0	1116
Isopoda	Asellidae	*Caecidotea*	12279	23442	35442	23070	41860
Ephemeroptera	Heptageniidae	*Epeorus*	186	0	0	0	0
Diptera	Orthocladiinae	*Cricotopus*	558	558	372	744	0
Diptera	Orthocladiinae	*Eukiefferiella*	0	0	372	372	0
Diptera	Orthocladiinae	*Orthocladius*	0	0	744	0	0
Diptera	Chironominae	*Dicrotendipes*	186	0	0	0	0
Diptera	Tanytarsini	*Tanytarsus*	186	0	0	0	0
Diptera	Simuliidae		2233	0	1488	744	0
Total			27721	33488	47349	44279	50233

Spring Creek Spring
26-Mar-01

Macroinvertebrate density (individuals per m^2) in each replicate sample.

			XSC1A	XSC1B	XSC1C	XSC1D	XSC1E
Annelida	Oligochaetae		93	93	0	47	233
Decapoda	Cambaridae		0	47	0	47	47
Hydracarina			23	372	0	47	0
Ephemeroptera	Ephemerellidae	*Ephemera*	0	47	0	0	0
Ephemeroptera	Ephemerellidae	*Ephemerella*	2953	4000	1163	4047	3256
Ephemeroptera	Heptageniidae	*Stenacron*	0	0	0	0	47
Ephemeroptera	Heptageniidae	*Epeorus*	0	47	0	0	0
Ephemeroptera	Oligoneuridae	*Isonychia*	0	0	0	0	47
Trichoptera	Brachycentridae	*Micrasema*	70	2558	140	1163	605
Trichoptera	Glossosomatidae	*Glossosoma*	23	0	0	47	0
Trichoptera	Hydropsychidae	*Cheumatopsyche*	23	47	0	326	47
Trichoptera	Hydropsychidae	*Hydropsyche*	70	93	0	326	0
Trichoptera	Limnephilidae	*Pycnopsyche*	23	0	0	47	0
Coleoptera	Haliplidae	*Haliplus*	23	0	0	0	0
Diptera	Ceratopogonidae	*Probezzia*	47	0	23	0	0
Diptera	Diamesini	*Pagastia*	47	0	0	0	0
Diptera	Diamesini	*Diamesa*	0	0	23	0	0
Diptera	Orthocladiinae	*Cricotopus*	0	0	23	0	47
Diptera	Orthocladiinae	*Orthocladius*	0	0	0	93	0
Diptera	Orthocladiinae	*Eukiefferiella*	0	0	0	47	0
Diptera	Tanytarsini	*Rheotanytarsus*	70	2791	140	744	186
Diptera	Tanytarsini	*Tanytarsus*	0	0	0	47	0
Diptera	Tipulidae	*Antocha*	70	93	0	0	140
Diptera	Tipulidae	*Dicranota*	0	0	23	0	0
Bivalvia	Sphaeriidae	*Pisidium*	279	279	47	47	0
Gastropoda	Pleuroceridae	*Elimia*	23	0	0	0	0
Gastropoda	Physidae	*Physa*	0	0	0	47	0
Total			3837	10465	1581	7116	4651

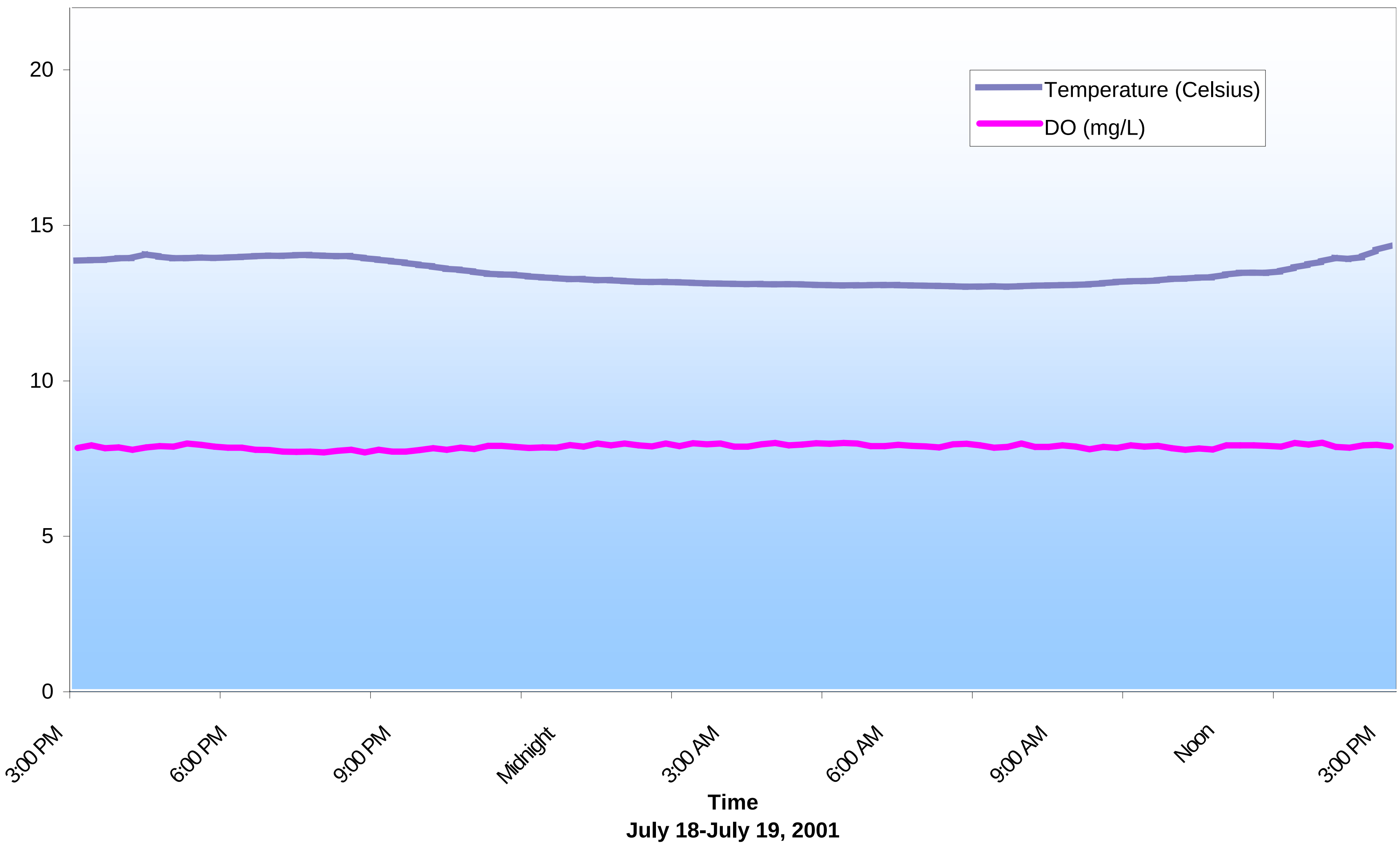
Glover Run Tributary
11/1/2001
Macroinvertebrate density (individuals per m^2) in each replicate sample.

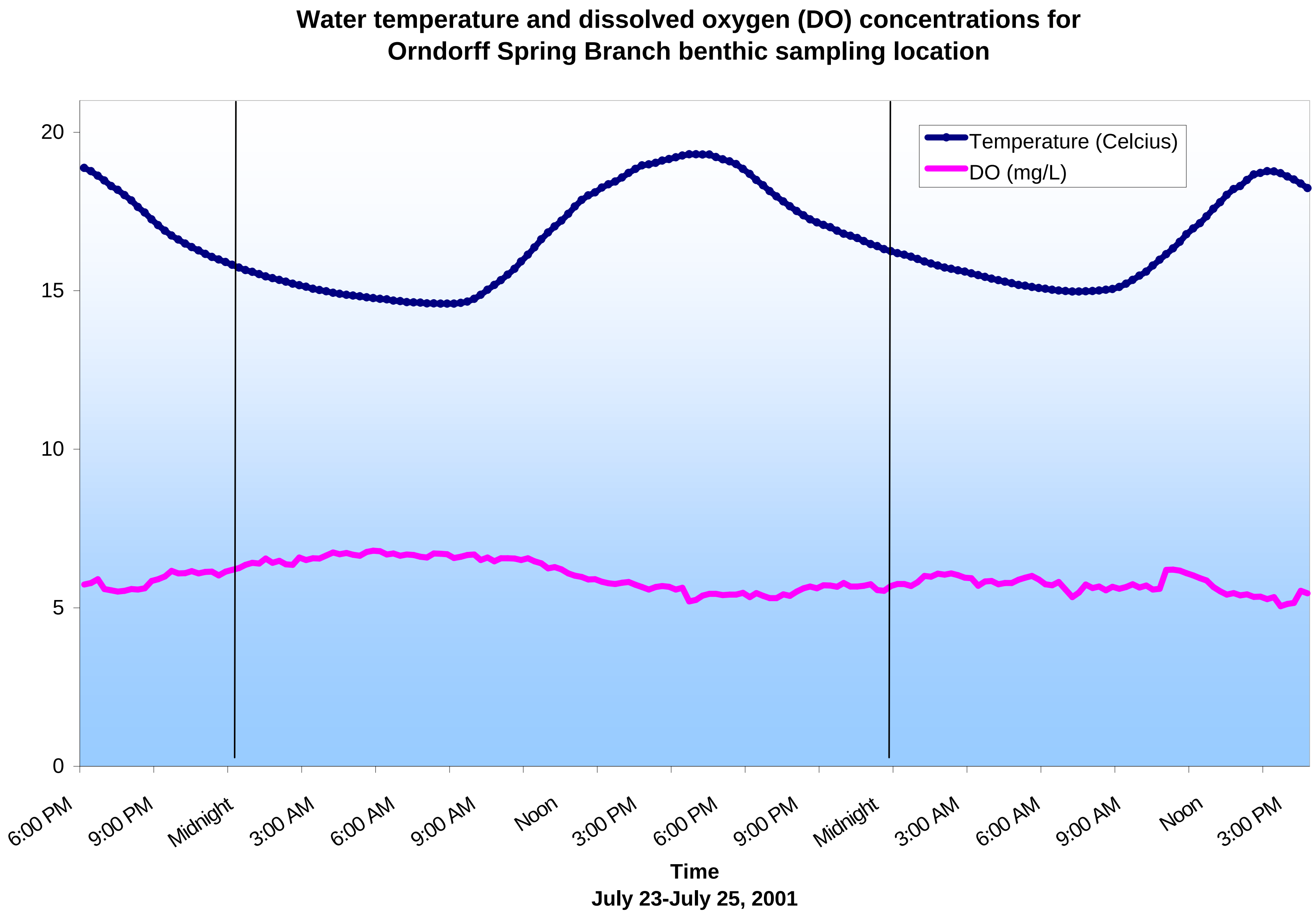
			XXGA	XXGB	XXGC	XXGD	XXGE
Annelida	Oligochaetae		0	116	0	0	47
Isopoda	Asellidae	*Caecidotea*	23	0	23	23	93
Ephemeroptera	Baetidae	*Baetis*	0	70	116	23	93
Ephemeroptera	Heptageniidae	*Epeorus*	0	0	12	23	0
Odonata	Gomphidae	*Gomphus*	116	70	58	256	93
Plecoptera	Nemouridae	*Amphinemura*	47	47	0	163	186
Plecoptera	Peltoperlidae	*Tallaperla*	93	0	12	23	140
Plecoptera	Perlidae	*Acroneuria*	23	279	35	0	47
Plecoptera	Perlidae	*Eccoptura*	0	0	12	0	0
Plecoptera	Perlidae	*Hansonoperla*	47	0	0	23	0
Plecoptera	Pteronarcyidae	*Pteronarcys*	0	0	0	23	0
Trichoptera	Hydropsychidae	*Diplectrona*	0	93	12	140	47
Trichoptera	Hydropsychidae	*Hydropsyche*	0	0	12	0	47
Trichoptera	Odontoceridae	*Psilotreta*	47	23	23	0	47
Trichoptera	Philopotamidae	*Wormaldia*	0	0	0	23	0
Trichoptera	Brachycentridae	*Brachycentrus*	0	0	0	23	0
Trichoptera	Lepidostomatidae	*Lepidostoma*	0	0	0	23	47
Trichoptera	Goeridae	*Goera*	0	0	0	23	0
Trichoptera	Limnephilidae	Immature	0	0	12	0	0
Trichoptera	Psychomyiidae	*Lype*	0	0	0	0	47
Trichoptera	Rhyacophilidae	*Rhyacophila*	0	93	0	70	93
Coleoptera	Elmidae	*Optiservus*	209	116	221	116	186
Coleoptera	Elmidae	*Oulimnius*	70	186	47	0	0
Coleoptera	Elmidae	*Stenelmis*	47	163	58	116	47
Coleoptera	Psephenidae	*Ectopria*	0	23	0	0	0
Coleoptera	Psephenidae	*Psephenus*	0	0	0	0	47
Diptera	Ceratopogonidae	*Probezzia*	23	70	0	0	93
Diptera	Diptera	Simuliidae	116	0	35	0	0
Diptera	Tanypodinae	*Conchapelopia*	0	23	0	0	0
Diptera	Orthocladiinae	*Eukiefferiella*	47	23	23	70	279
Diptera	Orthocladiinae	*Parametriocnemus*	0	23	0	0	0
Diptera	Tanytarsini	*Micropsectra*	0	23	0	0	0
Diptera	Tanytarsini	*Stempellina*	0	0	0	0	93
Diptera	Tipulidae	*Hexatoma*	23	23	0	0	47
Diptera	Tipulidae	*Tipula*	0	0	0	23	0
Bivalvia	Sphaeriidae	*Pisidium*	47	23	12	0	47
Gastropoda	Hydrobiidae	*Somatogyrus*	1465	233	221	744	2884
Gastropoda	Pleuroceridae	*Leptoxis*	0	23	0	0	0
Total			2442	1744	942	1930	4744

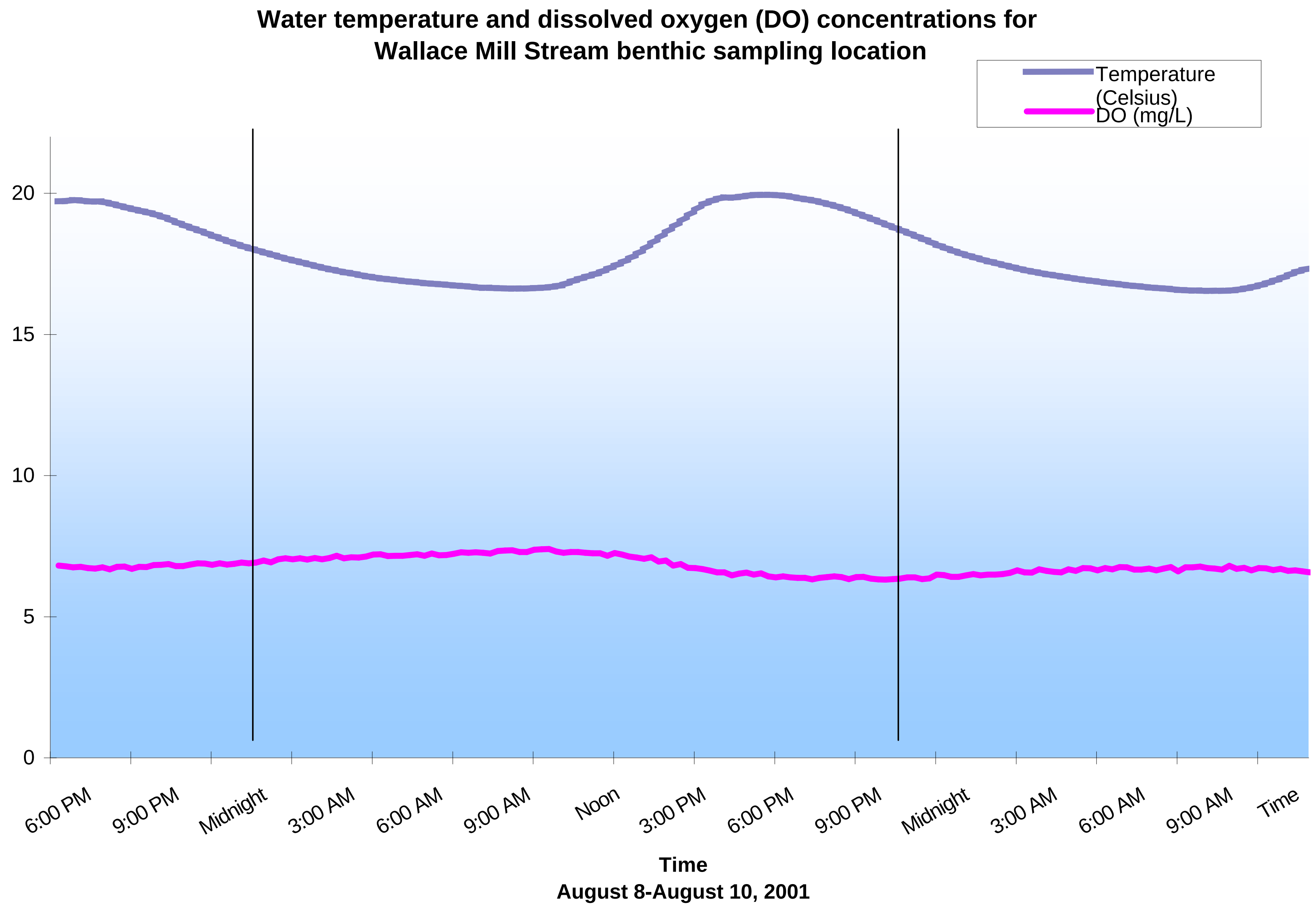
APPENDIX B - Water Temperature and Dissolved Oxygen Concentrations

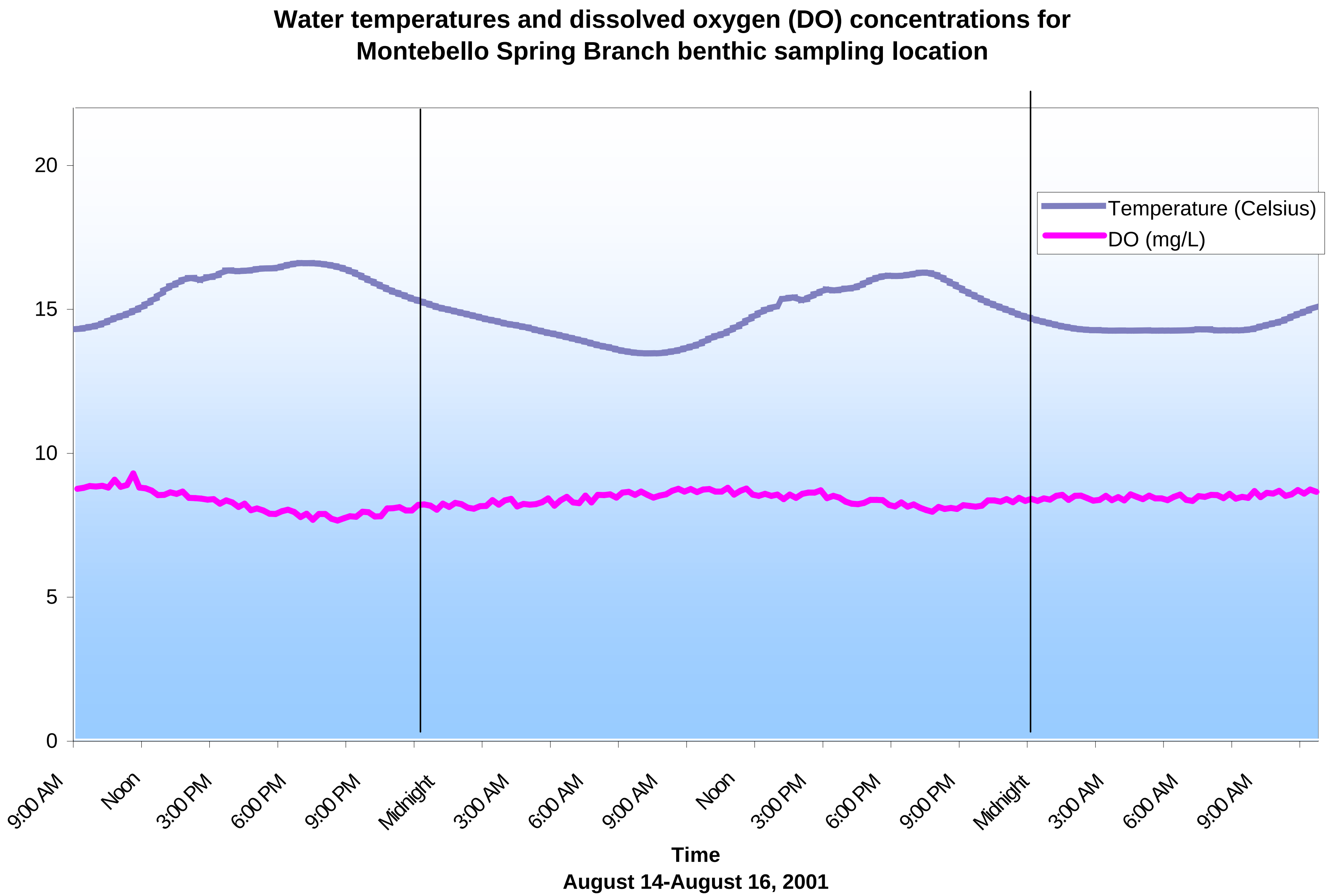
Montebello Spring Branch, July 18-July 19, 2001
Orndorff Spring Branch, July 23-July 25, 2001
Wallace Mill Stream, August 8-August 10, 2001
Montebello Spring Branch, August 14-August 15, 2001
Lacey Spring Branch, August 21-August 23, 2001

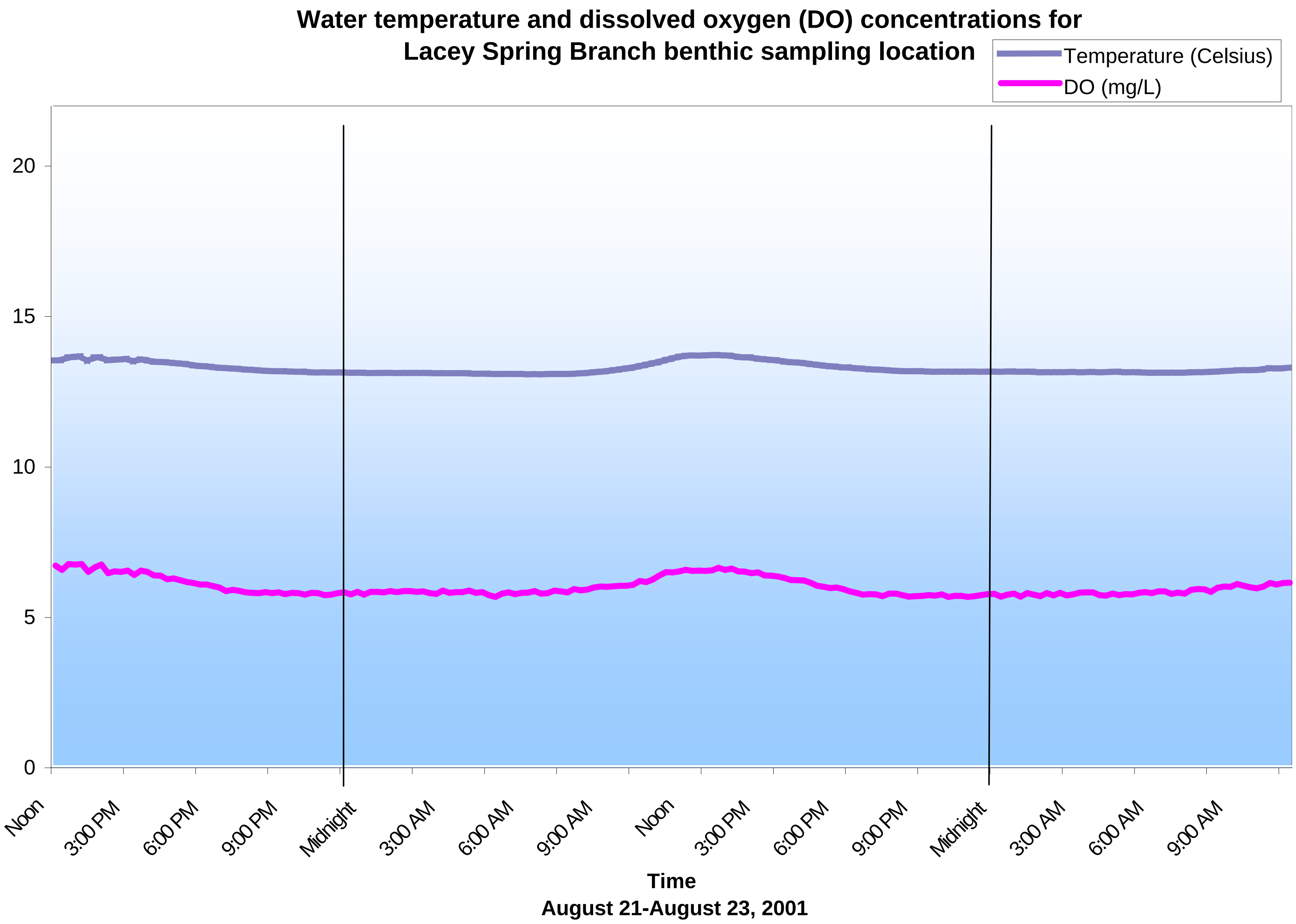
Water temperature and dissolved oxygen (DO) concentrations for Montebello Spring Branch benthic sampling location




Water temperature and dissolved oxygen (DO) concentrations for
Orndorff Spring Branch benthic sampling location
Temperature (Celcius)
DO (mg/L)
20
15
10
5
0
6:00 PM
9:00 PM
Midnight
3:00 AM
6:00 AM
9:00 AM
Noon
3:00 PM
6:00 PM
9:00 PM
Midnight
3:00 AM
6:00 AM
9:00 AM
Noon
3:00 PM
Time
July 23-July 25, 2001


Water temperature and dissolved oxygen (DO) concentrations for
Wallace Mill Stream benthic sampling location
Temperature (Celsius)
DO (mg/L)
0
5
10
15
20
6:00 PM
9:00 PM
Midnight
3:00 AM
6:00 AM
9:00 AM
Noon
3:00 PM
6:00 PM
9:00 PM
Midnight
3:00 AM
6:00 AM
9:00 AM
Time
Time
August 8-August 10, 2001


Water temperatures and dissolved oxygen (DO) concentrations for
Montebello Spring Branch benthic sampling location
0
5
10
15
20
Temperature (Celsius)
DO (mg/L)
9:00 AM
Noon
3:00 PM
6:00 PM
9:00 PM
Midnight
3:00 AM
6:00 AM
9:00 AM
Noon
3:00 PM
6:00 PM
9:00 PM
Midnight
3:00 AM
6:00 AM
9:00 AM
Time
August 14-August 16, 2001



Water temperature and dissolved oxygen (DO) concentrations for
Lacey Spring Branch benthic sampling location
Temperature (Celsius)
DO (mg/L)
0
5
10
15
20
Noon
3:00 PM
6:00 PM
9:00 PM
Midnight
3:00 AM
6:00 AM
9:00 AM
Noon
3:00 PM
6:00 PM
9:00 PM
Midnight
3:00 AM
6:00 AM
9:00 AM
Time
August 21-August 23, 2001

APPENDIX C - Fish Survey Results

Fish Survey of Lacey Spring Branch, Pheasanty Run, and Mount Solon Spring Branch

Trout were observed in greatest number in Lacey Spring Branch and Pheasanty Run. The fish may have escaped from the trout farms located on the streams or been stocked in the stream. Smith Creek, the receiving waters of Lacey Spring Branch, is privately stocked with trout. Pheasanty Run is a Virginia Department of Game and Inland Fisheries (DGIF) stocked trout stream. It is stocked once in October, once in November or December, once in January or February, and twice in March, April, and May.

A high density of drift-feeding trout in these streams may have lowered the macroinvertebrate abundance or affected the taxonomic composition, thereby biasing the DEQ's Rapid Bioassessment Protocol II analysis. A fish survey was conducted to determine the possible influence, if any, of trout on the macroinvertebrate community within the impaired stream segments.

Fish survey method

A quantitative fish survey was conducted for Lacey Spring Branch, Pheasanty Run, and their benthic macroinvertebrate reference stream, Mount Solon Spring Branch. Specifically, fish assemblages within a 100-m reach (approximate) were sampled using a model 12 Smith-Root electrofisher. All fish collected were identified to species and returned to the collection reach after processing. All activities represented standard fisheries procedures and followed appropriate quality assurance protocols.

The TMDL study team selected specific sampling locations (reaches) to be surveyed. Sampling was conducted during the week of 3 June 2001. Experts at Virginia Commonwealth University conducted the fish survey and data analysis.

Results

Mount Solon Spring Branch (Reference):

Six species of fish, including non-native salmonids (brown and rainbow trout) were represented in collections at this location. Relative abundance was 13.5 fish per minute.

Lacey Spring Branch:

Only a single species of fish, introduced rainbow trout, was collected in Lacey Spring Branch. The relatively low abundance of trout (5.3 fish per minute) in Lacey Springs Branch makes it unlikely that fish predation could bias significantly the RBP assessments.

Pheasanty Run:

Thirteen species of fish, including 133 introduced rainbow trout (*Oncorhynchus mykiss*) and 3 introduced brown trout (*Salmo trutta*) were represented in collections. Numerically dominant native species were the white sucker (*Catostomus commersoni*) and mottled sculpin (*Cottus bairdi*). Overall fish abundance was 9.9 fish per minute. The fish survey indicates that selective predation by relatively high densities of introduced trout in Pheasanty Run could affect the results of the benthic macroinvertebrate bioassessments; however, a more detailed study of trout feeding ecology would be necessary to test the hypothesis.

Table C.1 Results of fish survey conducted on June 7, 2001.

STREAM	GENUS	SPECIES	COLLECTED
MT SOLON SPRING BRANCH			
	COTTUS	bairdi	54
	MARGARISCUS	margarita	1
	ONCORHYNCHUS	mykiss	5
	SALMO	trutta	4
	RHINICHTHYS	atratulus	1
	CATOSTOMUS	commersoni	1
LACEY SPRING BRANCH			
	ONCORHYNCHUS	mykiss	31
PHEASANTY RUN			
	THOBURNIA	rhothoeca	1
	AMBLOPLITES	rupestris	2
	COTTUS	bairdi	22
	CAMPOSTOMA	anomalum	3
	RHINICHTHYS	cataractae	1
	ONCORHYNCHUS	mykiss	133
	SALMO	trutta	3
	SALVELINUS	fontinalis	1
	NOCOMIS	leptocephalus	5
	RHINICHTHYS	atratulus	2
	CATOSTOMUS	commersoni	47
	ERIMYZON	oblongus	1
	LEPOMIS	gibbosus	1

APPENDIX D - Percent Sediment-Bound TKN and TP

	TKN	FTKN	Sediment Bound %	TP	FTP	Sediment Bound %
Ingleside (n = 4)	0.193	0.059	69	0.042	0	100
Mt Solon (n = 4)	0.353	0.209	41	0.067	0	100
Mill Creek (n = 4)	0.813	0.319	39	0.117	0.079	33
Montebello						
Headwater (n = 8)	0.666	0.047	61	0.049	0.004	92
Outfall (n = 66)	1.469	0.500	66	0.277	0.051	82
Orndorff						
Headwater (n = 9)	0.866	0.364	59	0.020	0	100
Impaired Segment (n = 2)	1.338	0.396	70	0.050	0.006	85
Outfall (n = 55)	1.707	0.578	66	0.172	0.040	77
Pheasanty						
Headwater (n = 4)	0.179	0.146	18	0.043	0	100
Outfall (n = 5)	0.689	0.034	95	0.063	0	100
Benthic site (n = 4)	0.525	0.176	66	0.060	0	100
End of impairment (n = 4)	0.731	0.171	77	0.056	0	100
Cockran						
Headwater (n = 4)	0.330	0.197	40	0.030	0	100
Outfall (n = 4)	0.999	0.451	55	0.056	0	100
Beginning impairment (n = 5)	1.055	0.393	63	0.082	0	100
End of impairment (n = 4)	0.953	0.517	46	0.084	0	100
Lacey						
Headwater (n = 5)	0.733	0.426	42	0.098	0	100
Outfall (n = 31)	0.750	0.414	45	0.098	0	100
Benthic site (n = 2)	0.337	0.123	64	0.086	0	100
Wallace Mill						
Headwater (n = 4)	0.379	0.283	25	0	0	0
Outfall (n = 34)	1.751	0.903	48	0.205	0	100
End of Impairment (n = 2)	0.944	0.299	32	0.040	0	100

APPENDIX E - Watershed Delineation Procedures

This document is designed for users experienced with the ArcView GIS software package. The user should have a working knowledge of the program and its extensions and should be able to perform basic actions such as adding a point, line or polygon theme to a view, adding a grid theme to a view, and loading extensions. Familiarity with WinZip or a similar compression/decompression program is assumed.

Overview of Data Used

The watersheds for six impaired stream segments in Virginia were delineated. The elevation data for the delineation consisted of 30 m (1:24,000) DEM's (digital elevation models). The data for selected counties were downloaded from the Radford University Department of Geography website at: http://www.runet.edu:8800/~geoserve/main_page.html.

Stream coverage was obtained from The GIS Data Depot® (gisdatadepot.com). The *hydrography 24K DLG* (digital line graph) data set (based on US census data) at the county level was used as a base stream map.

Digital Raster Graphics (DRG's) were used to visually verify the positions and existence of features in the stream coverage, as well as a visual check for the accuracy of the watershed delineation. DRG's are digital copies of standard 1:24,000-scale USGS topographic quadrangle sheets. The DRG's were also downloaded from the Radford University Department of Geography website.

Clipping the information collar (the white border surrounding a USGS topo map containing all information pertinent to the map) on the DRGs required the "Quadrangle Grid Index" downloadable from the Virginia Economic Development Partnership (VEDP) (http://gis.vedp.org/meta/metadata.html). The data were available in zipped format as an ArcInfo Interchange file (E00 format), which can be extracted using WinZip. Once unzipped, the Import 71 function found in the Environmental Systems Research Institute (ESRI) folder from the start menu was used to extract "*gridutm1727*" to the project folder as "*usqsboundary.shp.*"

Positions of outlet points for the watersheds were estimated based on downstream limits depicted in the maps provided in the Year 2000 303(d) Impaired Waters Fact Sheet for each impaired segment (VADEQ).

Data Preparation

The DEM grids were resampled to a 5 m grid cell size to account for the proximity of streams within the basins, and the grids were merged to provide a continuous coverage throughout the area of interest. The DRGs were clipped to remove the "information collar." Also, the DEM grids and DRG's had to be merged at sites where the watershed was likely to cover portions of multiple USGS topo quads. Additions to the stream coverage were made by digitizing streams near the study area from the corresponding USGS DRG's. Data preparation steps include DEM resampling, DRG clipping, and DEM and DRG merging. Procedures for these steps are described below.

DEM resampling procedure

1. Turn on the "Spatial Analyst extension" through the Extension dialog.
2. Add the DEM to the view as a grid theme and set the *Map Units* in the View - Properties dialog to meters.
3. In the Analysis Properties dialog, the *Analysis Extent* set to the DEM name and the cell size to 5 meters.
4. The Map Calculator function of the ArcView Spatial Analyst extension resamples the grid when *Map Calculation 1* is set equal to the DEM name by double-clicking the DEM name and selecting "Evaluate."
5. Save *Map Calculation 1* using the *Theme - Save Data Set* function and store it in the project file.

DRG clipping procedure

1. Download DRG's from the Radford University Department of Geography website as image files (TIFF) with the corresponding reference file to display it in the correct coordinates.
2. Convert the images to grids in ArcView in order to clip and merge them when necessary by making the tiff image active and choosing the Theme – Convert to Grid option from the menu bar.
3. Clip the collars using the ArcView Spatial Analyst extension in combination with a user script named *milagrid.avx*, which is available for download as a Zip file at http://gis.esri.com/arcscripts/scripts.cfm.
4. Extract the "milagrid.avx" file to the C:\ESRI\AV_GIS30\ARCVIEW\EXT32 folder.
5. In the project "View" window, select the File – Extensions option and scroll down to *MILA Grid Utilities 1.3* and click the box to turn on the extension.
6. Add the DRGs you wish to clip as a grid data source.
7. Load the "usgsboundary.shp" file as a feature data source.
8. Turn on both themes and zoom to the extent of the DRG.
9. Using the select tool, pick the individual polygon in *usgsboundary.shp* that corresponds to the DRG.
10. Make both the DRG grid theme and the polygon boundary theme active by clicking on them while holding down the shift key and click the Clip Grid button.
11. Click "Yes" to answer all questions and save the data set to the project folder.
12. In order to view the clipped grid as an image with the correct coloring, the colormap file, *usgs.clr* (available at http://filebox.vt.edu/users/jaander1/) should be copied and the name changed to match that of the clipped grid (e.g. "clippedgrid.clr").
13. Place the colormap file for the clipped grid in the same folder as the folder with the name of the clipped grid, not in the clipped grid folder itself (See Figure E.1).
14. Once the grid is clipped and the colormap file named and placed in the correct folder, load the clipped DRG as an image data source to view it as a clipped, correctly colored USGS topographic quad sheet.

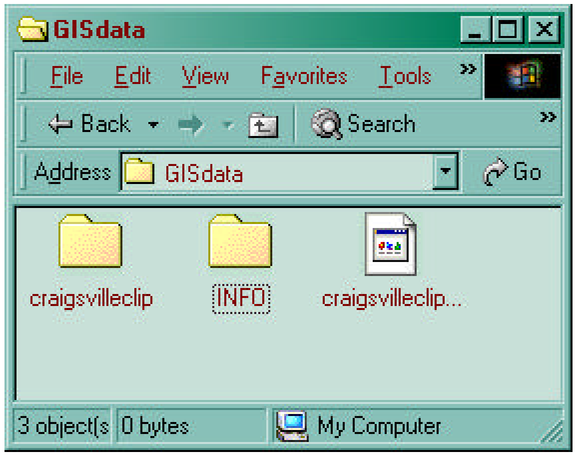


Figure E.1

DEM and DRG merging procedure

1. Merge both DEM's and DRG's using the ArcView Spatial Analyst extension in combination with a user script named "ggmosaic.ave", which is available for download at http://gis.esri.com/arcscripts/scripts.cfm.
2. Go to the project window and select Scripts, then select New.
3. Click the Load Text File button (the open folder) and navigate to the location of "ggmosaic.ave."
4. Load the script and compile it by clicking the Compile button (the check mark).
5. In the project window, select Views and then open a view.
6. Double-click any blank portion of the menu bar to access the "Customize *projectname*" window.
7. Select Buttons in the Category drop down list.
8. Click New to add a new button to the menu bar.
9. Double-click Click in the list at the bottom of the dialog box and navigate to the script you just created (e.g. "Script1") and choose OK.
10. Close the "Customize *projectname*" window.
11. Back in the project "View" window, add the DEMs and/or DRGs you wish to merge as a grid data source.
12. Select the grids by clicking on them while holding down the shift key.
13. Click the button you created earlier to begin the grid merging process.
14. Navigate to the project folder and click OK to merge the grids.

Delineation Procedure

The watersheds were delineated using the CRWR PrePro ArcView preprocessor, developed by the GIS Research Group at the Center for Research in Water Resources (CRWR) at the University of Texas at Austin. Information on the preprocessor is available at: http://www.ce.utexas.edu/prof/olivera/prepro/prepro.htm.
The basic steps to the process are:
1. **Fill Sinks** – tells ArcView to fill the sinks so they are level with the surrounding terrain. Note that only tiny sinks will be filled, since large sinks, such as ponds, are real sinks and should not be removed from the DEM.

2. **Burn Streams** – overlays the stream coverage onto the elevation grid and determines which cells in the DEM intersect the existing stream bed. It then adds an arbitrary value (5000 is the default) to every cell that does not intersect the stream coverage. This step ensures that any drainage networks and watersheds calculated by the program will follow the existing stream network.
3. **Flow Direction** – looks at every cell in the DEM in relation to the eight cells surrounding it (N, NE, E, SE, S, SW, W, and NW) and determines which of these cells provides the steepest slope. For example, in a 30 meter grid, a random cell with an elevation value of 200 meters is surrounded by the following cells: N, 222; NE, 199; E, 190; SE, 197; S, 197; SW, 198; W, 188; and NW, 200. The flow direction for the random cell in this example will be assigned to its neighbor to the west because it provides the greatest slope ((200-188)/30*100 = 4.0%)
4. **Flow Accumulation** – addresses each cell of the DEM and counts how many upstream cells contribute to flow through the given cell.
5. **Stream Definition** – defines the drainage area on the DEM, which corresponds to a user-defined minimum number of cells [Threshold], which will contribute to a stream. In this study, a threshold of 6.2 acres was used to define the streams (1000 cells X 25 m^2/cell X 1 acre/4,047 m^2).
6. **Add Streams** – adds streams to your stream grid. This may be handy if you are modeling flows at stream gages, or biological monitoring stations in an area and need to extend a stream to a given gage location.
7. **Stream Segmentation** – identifies stream segments or links, which start at either the beginning of a stream or where two streams intersect and end at a downstream split in the stream or at the exit point of the system.
8. **Outlets from Links** – identifies the most downstream cell of a stream segment as a potential watershed outlet.
9. **Add Outlets** – adds outlets to system that are not the lowest points of the links. When adding outlets, the stream segments grids and outlets from grids are updated to account for the outlets. This function was used to add any outlet points that were not located at stream intersections
10. **Sub-Watershed Delineation** – delineates the sub-watersheds in the basin as grid files.
11. **Vectorize Streams/Vectorize Watersheds** – converts gridded streams and watersheds to a vector form as ArcView shapefiles.
12. **Dissolve Dangling Polygons** – dissolves dangling polygons, which are small areas of land which have become separated from the rest of their sub-watershed polygon due to the raster-to-vector conversion process.

These descriptions have been adapted from 1998 class notes posted on the Internet by Ahrens et al. at the University of Texas (http://www.crwr.utexas.edu/gis/gisenv98/class/GISex/ex298/prepro.htm).
For a tutorial on how the program works:
http://www.crwr.utexas.edu/gis/gishydro99/watchar/ExerciseDelineate/delinex.htm

Final Editing and Verification

The subwatersheds upstream of each outlet point were selected from the CRWR Prepro output file and saved as a separate layer. The area (m^2) and acreage of the selected subwatersheds for each site were calculated using the Calculator function available in the table menu bar in the ArcView software package. The steps are as follows:
Click the Open Theme Table button and choose Table – Start Editing to begin editing the theme. Add a new number field (Edit – Add New Field) named *"area"*. Be sure that no records are selected in the table and click the heading of the *area* field to make it active. Click the Calculate button and double click *Shape.*

Enter the text ".returnarea" to complete the area calculation formula. The dialog box must contain "[Shape].returnarea" to calculate the polygon area properly. This area is calculated in the units of the shapefile (in this case, meters). In order to convert the area to acres, a new field is created, and the Calculate function used again. This time the text in the dialog box should be "[area]/4046.856" in order to convert m^2 to acres.

The subwatersheds are then dissolved and the areas and acreages summed for each site. Finally, the boundaries of the delineated watersheds are checked against the contour lines on the DRG's.

APPENDIX F - Visual Survey Procedures

Defining the Visual Survey

The objective of the visual survey was to document environmental conditions with potential to affect the benthic community. The visual survey involved observing and cataloging water and land conditions, land and water uses, and the changes that take place along defined stream segments. The survey method for this TMDL report was based on *Stream Corridor Assessment (SCA) Survey Protocols* developed by the Maryland Department of Natural Resources (Yetman 2000) and sections of the methods presented in EPA's *Volunteer Stream Monitoring: A Methods Manu*al (EPA 1997).

Each visual survey was conducted on a section of stream and 100 feet perpendicular to each stream bank along the designated section. The length of the segment surveyed was based on the physical characteristics of the stream and its riparian zone. The survey team consisted of a minimum of two people, who walked the total length of the stream segment. The team recorded the upper and lower boundaries of the designated stream segment with a global positioning system (GPS) and catalogued specific environmental conditions with digital photographs.

Visual Survey Documentation

The visual survey was conducted for the six impaired stream segments and the three reference streams (Ingleside Spring Branch, Mill Creek, and Mount Solon Spring Branch). The following attributes were documented for each stream segment:

- Weather at the time of the survey and in the prior 24 hours
- Locations of specific land uses (streamside, within ¼ mile, within watershed)
- Stream habitat types (pool, riffle, run)
- Soil texture of the stream bottom (silt, gravel, etc.)
- Embeddedness of the stream bottom
- Large woody debris in the stream channel
- Organic material in the stream (leaves, twigs, etc.)
- Appearance and odor of the water
- Width and depth of the stream
- Slope and condition of the stream banks (gradual/steep, percent modification)
- Land cover along the stream (trees, pavement, lawns, etc.)
- Presence of wildlife, fish, aquatic plants and algae

Environmental Conditions

The Maryland Department of Natural Resources protocol designates and describes nine environmental conditions to be included in a complete visual survey. Environmental conditions documented in the visual survey of the stream and its riparian zone include:

- channel alterations,
- erosion,
- exposed pipes,
- pipe outfalls,
- fish barriers,
- inadequate buffer zones,
- in and near stream construction,
- trash dumping sites, and
- unusual conditions.

A brief description of each condition is outlined below.

<u>Channel Alterations</u>

Any section of stream that has been altered from its natural course through widening, straightening, or artificial channel construction is considered a channel alteration. Channelized streams often offer a poor aquatic habitat for macroinvertebrates and fish and act as fish barriers. Construction of the channel alteration frequently creates an inadequate buffer zone. The type of channel alteration and the length of the channelized section were recorded.

<u>Erosion</u>

Erosion is a natural process, but when land use within a watershed is altered, erosion can cause unstable stream banks, destroy in-stream habitats, and cause severe sediment pollution downstream. Each erosion site was estimated for bank height and length.

<u>Exposed Pipes</u>

Exposed pipes are closed pipes either in the stream or along the stream bank that could be damaged during high flow events. The type of pipe was noted as well as any evidence of discharge.

<u>Pipe Outfalls</u>

Pipe outfalls are any pipes or small, man-made channels that discharge directly into the stream. Pipes may discharge uncontrolled effluent from a wide variety of sources. Runoff carried in stormwater pipes and ditches often carries petroleum products and heavy metals from parking lots and roads. Drainage ditches may transport fertilizers and pesticides from nearby agricultural fields. The color and odor of discharge, if any, was documented.

Fish Barriers

Fish barriers are natural or man-made structures that interfere with the upstream movement of fish. Fish barriers can cause isolation of fish populations, with consequences for repopulation, diversity, and the natural balance of the biological community. The type of barrier was noted and described as temporary or permanent and as partially or totally blocking the stream channel.

Inadequate Buffer Zones

Forested buffers stabilize stream banks, control nutrient cycling, reduce water velocity, provide cover and food for fish, and intercept solar radiation. For the purpose of the visual surveys completed in this study, an "inadequate buffer zone" had less than 25 feet of trees and other tall vegetation on either side of the stream.

In or Near Stream Construction

If proper precautions are not taken, construction can cause major aquatic disturbances, such as excess sediment reaching the stream. No construction in or near any of the six impaired stream segments was observed during the TMDL study period.

Trash Dumping

Trash, such as partially empty cans of motor oil, large barrels, tires, etc. dumped along the stream corridor can impact the biological and chemical properties of the water. The amount and type of trash was described.

Unusual Conditions

The unusual condition option serves as a “catch-all” to record data on any situation that may be affecting water quality but is not covered in any of the other environmental conditions. Unusual conditions can be manmade or natural. Livestock with access to the stream was most often recorded for this condition.

Processing the Information

As a precursor to the visual survey, a watershed boundary map was created (Appendix E). The visual survey was completed on a Personal Digital Assistant (PDA). The chosen software was a freeware package known as CyberTracker™, which was adapted to suit the needs of the visual survey. The users scrolled through the program marking and cataloguing the data described above. The PDA was equipped with a GPS unit to record the positions of the stream segment boundaries as well as the location of each identified environmental condition. The data were transferred to ArcView®, and the locations of the environmental conditions were marked on the watershed map. Digital photographs were also linked to the corresponding observed environmental condition.

APPENDIX G - Water Sampling and Flow Rate Measurement Procedures

Water Sampling and Flow Rate Measurements of Impaired Segments, Reference Streams, Side Streams, and Headwaters

Sampling Protocols

For each impaired segment, water samples were collected at the headwaters. For most sites, water samples were also collected within the impaired segment near the DEQ benthic sampling location, near the end of the impairment, and within any streams entering the impaired segment. Specific sampling locations are described for each impaired segment. Water samples were also collected at the DEQ benthic sampling locations within the reference streams: Ingleside Spring Branch, Mill Creek, and Mount Solon Spring Branch. Sampling for summer conditions occurred between July 18, 2001, and September 24, 2001. Sampling for winter conditions occurred between January 26, 2002, and February 2, 2002.

For each water sample, a 1-liter (L) bottle was filled for suspended solids analyses and a 500-milliliter (mL) bottle was filled for the other laboratory analyses. The water samples in the 500 mL bottles were stored on ice. The samples were returned to the Biological Systems Engineering Laboratory at Virginia Tech within 48 hours of sample collection. Samples were analyzed in the laboratory for the following parameters: total suspended solids (TSS), total settleable solids (SS), total dissolved solids (TDS), alkalinity, hardness, dissolved organic carbon (DOC), ammonia, nitrate, nitrite, Total Kjeldahl nitrogen (TKN), filtered TKN, total phosphorus (TP), filtered TP, and ortho-phosphate. Standard protocols were followed for sample analysis.

Field Measurements

Four parameters were measured in the field at the time of water collection: water temperature, pH, conductivity, and dissolved oxygen. Water temperature (^{o}C) was measured with a Traceable® thermometer for the samples collected in the summer and fall (July – September, 2001), and with a Multi-thermometer from Fisher Scientific in January and February 2002. The pH of the water was measured with either a Corning pH-30 meter or a Hach pH meter. The pH meter was calibrated before taking the first sample of the day with standard solutions for a pH of 7 and either a pH of 4 for waters below 7 or a pH 10 for waters above 7. Conductivity (µS/cm) of the stream water for the summer and fall samples were measured with a Corning CD-55 probe, and conductivity in the winter was taken with a Corning PS 17 and calibrated with a 90 µS/cm standard solution. A Dissolved Oxygen CHEMets® test, which uses the indigo carmine method, was used to estimate dissolved oxygen levels (mg/L).

A Hydrolab Datasonde 4 was used to measure water temperature (^{o}C) and dissolved oxygen levels (mg/L) every 15 minutes over the course of one or two days in four of the impaired stream segments: Montebello Spring Branch, Orndorff Spring Branch, Wallace Mill Stream, and Lacey Spring Branch. The Datasonde was set up according to Hydrolab instructions, and placed in the impaired stream near the DEQ benthic sampling location for the duration of the intensive water-sampling period at the trout farm facility (see section below on intensive sampling).

Flow Rate Measurements

Stream flow was measured for each impaired stream segment near the DEQ benthic sampling location. For most sites, stream flow was also measured near the end of the impairment and within any streams entering the impaired segment. Specific stream flow locations are described for each impaired segment. Flow was also measured at the DEQ benthic sampling locations within the reference streams: Ingleside Spring Branch, Mill Creek, and Mount Solon Spring Branch.

The velocity-area method was used. Stream flow (Q) was calculated by multiplying the average stream velocity (V) by the cross-sectional area of the stream (A): $Q = V \times A$. The average velocity was measured in feet per second and the cross-sectional area was measured in square feet to provide a flow measurement in cubic feet per second (cfs).

A Global Flow Probe EP101 from Global Water was used to estimate average stream velocity by moving it uniformly through the measured segment for approximately 20-40 seconds (The probe was calibrated before its use in this study, in the middle of the sampling period, and near the end of the sampling period.). The probe automatically calculated an average velocity. For small streams (generally, less than six feet wide) and pipes, the probe was moved back and forth across the water in the top, middle, and bottom sections of the flow. At least three average velocity readings were taken with the probe for small streams and pipes, and the average of these velocities was used in the stream flow calculation. For larger streams, a cross section of the stream was divided into segments in an attempt to have no more than 5% of the total flow in each segment. An average velocity for each segment was measured by moving the probe slowly between the surface and the bottom for 20-40 seconds.

The Global Flow Probe EP101 was unable to detect flow in two very small streams (a stream entering Wallace Mill and a wet weather spring that enters Orndorff Spring Branch). On these two occasions, velocity was estimated by recording the time it took a float to move a measured distance.

The cross-sectional area of the stream was estimated by adding the areas of individual stream segments. The cross-section of each stream was divided into regular intervals, and the depth at each interval was recorded. The area of the segment was estimated by multiplying the depth of the segment by the width of the segment. For round pipes, the filled area was determined by measuring the depth of the water and comparing it to the inside diameter of the pipe, as described in the Global Flow Probe EP101 Instruction Manual.

Intensive Water Sampling and Flow Rate Measurements of Trout Farm Effluents for Point Source Assessment

Sampling Protocols

The objective of the intensive sampling was to determine changes in discharge water quality in terms of spikes and peaks during periods of various farm activities, e.g., fish feeding, fish harvesting, and sediment trap/settling-basin cleaning. Unless otherwise noted, sampling took place at the trout farm outfall. Sample collection began soon after the start of the activity and continued at approximately five-minute intervals for a half hour to an hour. At four trout rearing facilities, intensive water sampling of the effluent occurred during fish feeding and harvesting (or simulated harvest), and during the cleaning of a sediment trap/settling basin. At two trout facilities, intensive sampling of the effluent occurred during two fish feedings and a fish harvest conducted before cleaning the sediment trap/settling basin, and again during these activities approximately 24 hours after the settling basin was cleaned. Sampling for summer conditions occurred between July 18, 2001, and September 24, 2001. Sampling for winter conditions occurred between January 26, 2002, and February 2, 2002. In addition to water samples, eight to nine samples of the solids that had settled in a sediment trap/settling basin were collected at three of the trout rearing facilities. The solid samples were analyzed for volatile solids.

Water sample protocols and field measurements taken at the time of water sample collection follow the same procedures described earlier (See Sampling Protocols and Field Measurements).

Flow Rate Measurement

The velocity-area method described earlier was used to calculate the flow of the effluent from the trout rearing facilities. Effluent flow was measured directly at three of the farms where intensive sampling occurred. At some sites, effluent flow through the trout rearing facility was estimated by subtracting the measured flow of any entering upstream channels from the flow calculated in the stream immediately downstream of the entering effluent. At one trout rearing facility, the exiting flow split into two channels, with the majority of the water flowing through a concrete channel to the impaired stream and some of the effluent feeding an adjacent pond. Total flow for this facility was estimated by adding the measured flows from the concrete channel and the pond outfall.

Laboratory Methods

References
Standard Methods for the Examination of Water and Wastewater 20th edition 1998
Eds. Lenore S. Clesceri, Arnold E. Greenburg, Andrew D. Eaton

Methods for Chemical Analysis of Water and Wastes EPA –600/4-79-020
Revised 3/1983

Method Numbers	Instrument Method
Alkalinity EPA 310.1	
Ammonia EPA 350.1	Bran + Luebbe US-780-86C
Dissolved Organic Carbon EPA 415.2	
Hardness SM 2340 B	
Nitrate EPA 353.1	Bran + Luebbe 782-86T
Nitrite EPA 353.1	Bran + Luebbe 784-86T
Orthophosphate EPA 365.1	Bran + Luebbe US-781-86D
Phosphorus EPA 365.4	Bran + Luebbe US-787-86C
Total Dissolved Solids SM 2510 A, B	
Total Kjeldahl Nitrogen EPA 351.2	Bran + Luebbe US-786-86B
Total Settleable Solids EPA 160.5	
Total Suspended Solids EPA 160.2	
Volatile Solids EPA 160.4 and SM 2540 E, G	

Method Detection Limits

Alkalinity		0-500 mg/L
Ammonia		0.008-3.0 mg/L
Dissolved Organic Carbon		0.01-50 mg/L
Hardness	Calcium 0.001-10000 mg/L	Magnesium 0.001-5000 mg/L
Nitrate		0.002-2.0 mg/L
Nitrite		0.002-2.0 mg/L
Orthophosphate		0.01-2.0 mg/L
Phosphorus		0.01-2.0 mg/L
Total Dissolved Solids		0.01-200000 mg/L
Total Kjeldahl Nitrogen		0.04-2.0 mg/L
Total Settleable Solids		0.1-1000 mL/L
Total Suspended Solids		0.001-20000 mg/L
Volatile Solids		0.001-20000 mg/L

APPENDIX H - Laboratory Analysis Results

Water Samples:
Ingleside Spring Branch
Mount Solon Spring Branch
Mill Creek
Cockran Spring Branch
Lacey Spring Branch
Orndorff Spring Branch
Pheasanty Run
Wallace Mill Stream
Montebello Spring Branch

Solids Samples from Trout Facilities:

Montebello Spring Branch
Orndorff Spring Branch
Wallace Mill Stream

Water Sample Analysis Results for Ingleside Spring Branch

(See Appendix G for detection limits)

Ingleside Spring Branch					
Code		1ING1	2ING1	3ING1	4ING1
Date		7/23/01	9/20/01	9/23/01	1/27/02
Time		11:50 AM	10:05 AM	10:45 AM	5:15 PM
Cond.	µS/cm	310	313	311	180
Temp.	^{o}C	16.8	15.0	15.7	10.3
pH		7.6	7.8	8.0	7.4
DO	Mg/L	9	10	11	7
Alkalinity	Mg/L	148	147	149	129
Hardness	Mg/L	170	162	165	150
DOC	Mg/L	2.91	0.82	0.84	1.08
TSS	Mg/L	0.000	1.579	4.048	0.000
TDS	Mg/L	203	213	215	180
SS	ML/L	0.0	0.0	0.1	0.0
Nitrate	Mg/L	0.666	0.516	0.402	0.638
Nitrite	Mg/L	0.000	0.000	0.000	0.000
Ammonia	Mg/L	0.013	0.000	0.000	0.000
TKN	Mg/L	0.509	0.181	0.082	0.000
FTKN	Mg/L	0.235	0.000	0.000	0.000
Ortho-P	Mg/L	0.016	0.000	0.000	0.000
FTP	Mg/L	0.000	0.000	0.000	0.000
TP	Mg/L	0.000	0.086	0.081	0.000

Water Sample Analysis Results for Mount Solon Spring Branch

(See Appendix G for detection limits)

Mount Solon Spring Branch					
Code		1MSS1	2MSS1	3MSS1	4MSS1
Date		8/2/01	8/20/01	8/23/01	1/26/02
Time		3:15 PM	6:55 PM	1:40 PM	3:47 PM
Cond.	µS/cm	200	179	184	230
Temp.	^{o}C	17.0	15.7	13.9	11.5
pH		8.9	8.7	7.9	9.1
DO	mg/L	11	11	7	9
Alkalinity	mg/L	82	70	74	86
Hardness	mg/L	98	94	89	103
DOC	mg/L	0.65	1.41	0.74	0.96
TSS	mg/L	3.133	2.069	1.163	1.359
TDS	mg/L	124	122	134	129
SS	mL/L	0.0	0.0	0.0	0.0
Nitrate	mg/L	1.768	1.139	1.519	0.876
Nitrite	mg/L	0.091	0.000	0.014	0.000
Ammonia	mg/L	0.058	0.000	0.000	0.013
TKN	mg/L	0.830	0.582	0.000	0.000
FTKN	mg/L	0.560	0.275	0.000	0.000
Ortho-P	mg/L	0.050	0.000	0.000	0.000
FTP	mg/L	0.000	0.000	0.000	0.000
TP	mg/L	0.000	0.186	0.083	0.000

Water Sample Analysis Results for Mill Creek

(See Appendix G for detection limits)

Mill Creek (Rained 7/18/01)					
Code		1MC1	2MC1	3MC1	4MC1
Date		7/18/01	7/19/01	7/19/01	1/29/02
Time		3:45 PM	9:40 AM	1:55 PM	12:25 PM
Cond.	µS/cm	15	16	16	10
Temp.	^oC	16.1	15.4	15.8	7.6
pH		7.0	7.2	7.2	7.4
DO	mg/L	7	8	8	8
Alkalinity	mg/L	4	3	5	2
Hardness	mg/L	4	3	3	3
DOC	mg/L	2.63	4.92	2.93	1.10
TSS	mg/L	0.000	0.000	18.571	0.189
TDS	mg/L	10	10	10	10
SS	mL/L	0.0	0.5	0.0	0.0
Nitrate	mg/L	0.191	0.181	0.178	0.093
Nitrite	mg/L	0.000	0.000	0.000	0.000
Ammonia	mg/L	0.450	0.597	0.489	0.000
TKN	mg/L	1.162	1.096	0.994	0.000
FTKN	mg/L	0.234	0.454	0.589	0.000
Ortho-P	mg/L	0.000	0.000	0.000	0.000
FTP	mg/L	0.084	0.147	0.087	0.000
TP	mg/L	0.164	0.150	0.153	0.000

Water Sample Analysis Results for Cockran Spring Branch

(See Appendix G for detection limits)

Cockran Spring Branch
Headwaters

Code		1CH1	2CH1	3CH1	4CH1
Date		8/3/01	8/7/01	9/24/01	1/29/02
Time		11:05 AM	12:23 PM	10:36 AM	4:40 PM
Cond.	µS/cm	348	355	313	250
Temp.	^{o}C	13.0	13.1	13.1	13.3
pH		7.5	7.6	7.5	7.4
DO	mg/L	8	7	7	8
Alkalinity	mg/L	156	156	159	162
Hardness	mg/L	178	182	184	187
DOC	mg/L	0.54	0.27	0.50	0.39
TSS	mg/L	0.000	0.000	0.000	0.204
TDS	mg/L	215	213	231	218
SS	mL/L	0.0	0.0	0.0	0.0
Nitrate	mg/L	3.355	2.243	2.203	2.129
Nitrite	mg/L	0.085	0.000	0.000	0.000
Ammonia	mg/L	0.030	0.000	0.000	0.000
TKN	mg/L	0.559	0.761	0.000	0.000
FTKN	mg/L	0.481	0.308	0.000	0.000
Ortho-P	mg/L	0.056	0.000	0.000	0.000
FTP	mg/L	0.000	0.000	0.000	0.000
TP	mg/L	0.081	0.000	0.039	0.000

Cockran Spring Branch
Side Stream

SS=Side Stream (4 cattle upstream on 8/3/01. 8 cattle upstream on 8/7/01);
SSU=Upper part of side stream (Low water; disturbed bottom when sampling).

Code		1CSS1	2CSS1	3CSSU1	3CSS1	4CSS1
Date		8/3/01	8/7/01	9/24/01	9/24/01	1/29/02
Time		11:12 AM	12:36 PM	11:30 AM	11:18 AM	4:50 PM
Cond.	µS/cm	354	351	312	317	250
Temp.	^{o}C	14.8	16.0	13.8	14.2	13.0
PH		7.7	7.7	7.6	7.6	7.7
DO	mg/L	8	8	7	7	7
Alkalinity	mg/L	157	157	156	158	162
Hardness	mg/L	180	178	176	183	186
DOC	mg/L	1.23	2.29	0.78	0.79	0.67
TSS	mg/L	44.000	74.253	40.714	4.889	4.000
TDS	mg/L	218	222	234	239	212
SS	mL/L	0.5	1.5	0.2	0.0	0.0
Nitrate	mg/L	4.132	2.058	1.911	1.948	1.901
Nitrite	mg/L	0.093	0.003	0.000	0.000	0.000
Ammonia	mg/L	0.140	0.213	0.000	0.000	0.000
TKN	mg/L	1.962	2.372	0.186	0.147	0.000
FTKN	mg/L	1.216	1.894	0.000	0.000	0.000
Ortho-P	mg/L	0.070	0.278	0.000	0.000	0.000
FTP	mg/L	0.000	0.175	0.000	0.000	0.000
TP	mg/L	0.335	0.757	0.109	0.062	0.000

Cockran Spring Branch
Trout Farm Outfall
Fish in only one raceway on 8/3/01 and 8/7/01.

Code		1CO1	2CO1	3CO1	4CO1
Date		8/3/01	8/7/01	9/24/01	1/29/02
Time		11:28 AM	1:05 PM	12:00 PM	5:15 PM
Cond.	µS/cm	343	351	323	250
Temp.	^{o}C	14.2	15.0	13.3	13.0
pH		7.7	7.7	7.5	7.5
DO	mg/L	7	7	6	6
Alkalinity	mg/L	154	154	159	163
Hardness	mg/L	177	179	186	186
DOC	mg/L	0.58	0.55	1.13	0.99
TSS	mg/L	0.000	0.000	1.412	1.800
TDS	mg/L	217	216	243	229
SS	mL/L	0.1	0.0	0.2	0.1
Nitrate	mg/L	3.464	2.336	2.207	2.133
Nitrite	mg/L	0.090	0.000	0.000	0.015
Ammonia	mg/L	0.095	0.124	0.095	0.737
TKN	mg/L	1.023	1.003	0.882	1.092
FTKN	mg/L	0.518	0.562	0.106	0.619
Ortho-P	mg/L	0.063	0.019	0.000	0.045
FTP	mg/L	0.000	0.000	0.000	0.000
TP	mg/L	0.010	0.073	0.141	0.000

Cockran Spring Branch						
Beginning of Impairment						
3CBI1 taken upstream (below ford) of 3CBI2 (in cattle pasture).						
Code		1CBI1	2CBI1	3CBI1	3CBI2	4CBI1
Date		8/3/01	8/7/01	9/24/01	9/24/01	1/29/02
Time		10:50 AM	1:12 PM	1:24 PM	12:30 PM	5:40 PM
Cond.	µS/cm	342	354	328	325	250
Temp.	^{o}C	14.4	16.6	13.5	13.8	
pH		7.7	7.8	7.6	7.6	7.5
DO	mg/L	7	8	6	6	6
Alkalinity	mg/L	156	154	160	161	164
Hardness	mg/L	181	179	178	181	186
DOC	mg/L	0.67	0.77	1.09	0.92	1.08
TSS	mg/L	2.727	7.640	0.230	3.023	2.745
TDS	mg/L	215	215	235	243	218
SS	mL/L	0.0	0.0	0.0	0.1	0.1
Nitrate	mg/L	3.354	2.336	2.096	2.174	2.123
Nitrite	mg/L	0.095	0.000	0.000	0.000	0.013
Ammonia	mg/L	0.070	0.080	0.016	0.011	0.555
TKN	mg/L	1.286	1.254	0.975	0.753	1.007
FTKN	mg/L	0.623	0.889	0.000	0.045	0.407
Ortho-P	mg/L	0.070	0.029	0.000	0.000	0.038
FTP	mg/L	0.000	0.000	0.000	0.000	0.000
TP	mg/L	0.036	0.085	0.144	0.148	0.000

Cockran Spring Branch					
End of Impairment					
Code		1CEI1	2CEI1	3CEI1	4CEI1
Date		8/3/01	8/7/01	9/24/01	1/29/02
Time		11:55 AM	2:10 PM	10:00 AM	4:00 PM
Cond.	µS/cm	356	355	321	250
Temp.	^{o}C	20.0	24.3	14.5	14.8
pH		8.0	8.0	7.8	7.7
DO	mg/L	8	8	7	7
Alkalinity	mg/L	157	154	163	164
Hardness	mg/L	180	178	97	187
DOC	mg/L	0.81	1.00	1.32	1.18
TSS	mg/L	44.337	44.235	37.882	43.107
TDS	mg/L	217	216	251	222
SS	mL/L	0.2	0.1	0.3	0.2
Nitrate	mg/L	3.211	2.180	2.011	2.060
Nitrite	mg/L	0.144	0.039	0.016	0.053
Ammonia	mg/L	0.052	0.046	0.003	0.412
TKN	mg/L	1.284	1.180	0.748	0.601
FTKN	mg/L	0.764	0.826	0.205	0.272
Ortho-P	mg/L	0.076	0.019	0.000	0.053
FTP	mg/L	0.000	0.000	0.000	0.000
TP	mg/L	0.065	0.092	0.177	0.000

Water Sample Analysis Results for Lacey Spring Branch

(See Appendix G for detection limits)

Lacey Spring Branch Headwaters House=At spring house; H=Headwaters of trout farm						
Code		1LSHouse	1LSH1	2LSH1	3LSH1	4LSH1
Date		8/21/01	8/21/01	8/22/01	8/22/01	1/26/02
Time		3:45 PM	4:15 PM	10:35 AM	8:12 PM	10:17 AM
Cond.	µS/cm	674	690	680	672	420
Temp.	^{o}C	13.4	13.4	13.4	13.1	
pH		7.0	7.0	7.1	7.0	7.0
DO	mg/L	5		7	6	7
Alkalinity	mg/L	201	202	199	262	271
Hardness	mg/L	362	364	276	365	330
DOC	mg/L	1.35	1.32	1.12	1.31	1.12
TSS	mg/L	1.860	1.348	1.687	2.045	1.000
TDS	mg/L	379	386	290	358	412
SS	mL/L	0.0	0.0	0.0	0.0	0.0
Nitrate	mg/L	5.510	5.619	5.575	5.524	3.893
Nitrite	mg/L	0.000	0.000	0.000	0.000	0.000
Ammonia	mg/L	0.000	0.000	0.000	0.000	0.000
TKN	mg/L	0.860	1.091	0.795	0.921	0.000
FTKN	mg/L	0.457	0.780	0.443	0.448	0.000
Ortho-P	mg/L	0.002	0.000	0.000	0.000	0.000
FTP	mg/L	0.000	0.000	0.000	0.000	0.000
TP	mg/L	0.139	0.149	0.106	0.094	0.000

Lacey Spring Branch Trout Farm Outfall-No Activity					
Code		1LSNA1	2LSNA1	3LSNA1	4LSNA1
Date		8/21/01	8/22/01	8/22/01	1/26/02
Time		5:15 PM	8:50 AM	7:07 PM	9:41 AM
Cond.	µS/cm	682	672	670	420
Temp.	^{o}C	13.7	13.3	13.3	12.4
pH		7.2	7.1	7.2	7.0
DO	mg/L	6	6	6	7
Alkalinity	mg/L	251	241	265	273
Hardness	mg/L	351	351	355	331
DOC	mg/L	1.33	1.23	1.28	1.30
TSS	mg/L	2.759	2.791	2.093	0.189
TDS	mg/L	347	293	355	413
SS	mL/L	0.0	0.0	0.0	0.0
Nitrate	mg/L	5.530	5.422	5.435	3.956
Nitrite	mg/L	0.000	0.000	0.000	0.044
Ammonia	mg/L	0.000	0.000	0.000	0.230
TKN	mg/L	1.017	0.702	0.649	0.434
FTKN	mg/L	0.493	0.141	0.677	0.158
Ortho-P	mg/L	0.048	0.000	0.000	0.036
FTP	mg/L	0.000	0.000	0.000	0.000
TP	mg/L	0.099	0.092	0.125	0.000

Lacey Spring Branch								
Trout Farm Outfall-Feeding								
Started feeding at 9:24 a.m.; feeds a little throughout the day								
Code			1LSF1	1LSF2	1LSF3	1LSF4	1LSF5	1LSF6
Date			8/21/01	8/21/01	8/21/01	8/21/01	8/21/01	8/21/01
Time			9:30 AM	9:35 AM	9:40 AM	9:45 AM	9:55 AM	10:05 AM
Cond.	µS/cm	672						676
Temp.	^{o}C	13.4						13.4
pH		7.1						7.1
DO	mg/L	6						6
Alkalinity	mg/L		233	248	260	253	230	228
Hardness	mg/L		360	361	362	357	363	364
DOC	mg/L		1.38	1.40	1.47	1.48	1.54	1.33
TSS	mg/L		3.855	3.218	2.472	3.448	2.619	4.048
TDS	mg/L		350	391	336	362	313	335
SS	mL/L		0.0	0.0	0.0	0.0	0.0	0.0
Nitrate	mg/L		5.258	5.640	5.570	5.508	5.492	5.548
Nitrite	mg/L		0.000	0.000	0.000	0.000	0.000	0.000
Ammonia	mg/L		0.000	0.000	0.000	0.000	0.000	0.000
TKN	mg/L		0.972	0.776	0.888	0.659	0.683	0.644
FTKN	mg/L		0.254	0.367	0.382	0.490	0.367	0.365
Ortho-P	mg/L		0.007	0.004	0.000	0.000	0.000	0.000
FTP	mg/L		0.000	0.000	0.000	0.000	0.000	0.000
TP	mg/L		0.133	0.143	0.139	0.145	0.112	0.130

Lacey Spring Branch								
Trout Farm Outfall-Feeding								
Started feeding at 8:55 a.m.; feeds a little throughout the day								
Code			2LSF1	2LSF2	2LSF3	2LSF4	2LSF5	2LSF6
Date			8/22/01	8/22/01	8/22/01	8/22/01	8/22/01	8/22/01
Time			9:11 AM	9:18 AM	9:26 AM	9:35 AM	9:42 AM	9:55 AM
Cond.	µS/cm	672						
Temp.	^{o}C	13.4						
pH		7.1						
DO	mg/L	6						
Alkalinity	mg/L		250	269	260	264	261	272
Hardness	mg/L		348	349	353	353	350	356
DOC	mg/L		1.35	1.21	1.17	1.33	1.19	1.32
TSS	mg/L		2.791	3.488	2.439	2.410	3.256	3.448
TDS	mg/L		347	293	324	382	420	404
SS	mL/L		0.0	0.0	0.0	0.0	0.0	0.0
Nitrate	mg/L		5.445	5.377	5.383	5.382	5.370	5.475
Nitrite	mg/L		0.000	0.000	0.000	0.000	0.000	0.000
Ammonia	mg/L		0.000	0.000	0.000	0.011	0.000	0.000
TKN	mg/L		0.858	0.911	0.939	0.423	1.350	0.794
FTKN	mg/L		0.389	0.571	0.430	0.363	0.711	0.459
Ortho-P	mg/L		0.000	0.000	0.000	0.000	0.000	0.000
FTP	mg/L		0.000	0.000	0.000	0.000	0.000	0.000
TP	mg/L		0.111	0.101	0.074	0.079	0.109	0.102

Lacey Spring Branch
Trout Farm Outfall-Feeding
Started feeding at 8:45 a.m.; feeds a little throughout the day

Code			3LSF1	3LSF2	3LSF3	3LSF4	3LSF5	3LSF6	3LSF7
Date			8/23/01	8/23/01	8/23/01	8/23/01	8/23/01	8/23/01	8/23/01
Time			8:55 AM	9:08 AM	9:15 AM	9:21 AM	9:26 AM	9:35 AM	9:45 AM
Cond.	µS/cm	668							
Temp.	^{o}C	13.3							
pH		7.1							
DO	mg/L	6							
Alkalinity	mg/L		268	272	270	272	263	274	270
Hardness	mg/L		354	352	349	351	351	350	340
DOC	mg/L		1.23	1.19	1.25	1.12	1.16	1.25	1.23
TSS	mg/L		1.446	3.516	3.023	2.727	3.778	2.222	2.697
TDS	mg/L		376	371	379	330	350	400	345
SS	mL/L		0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitrate	mg/L		5.389	5.323	5.384	5.355	5.332	5.365	5.396
Nitrite	mg/L		0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ammonia	mg/L		0.000	0.000	0.000	0.003	0.006	0.000	0.000
TKN	mg/L		0.520	0.917	0.525	0.586	0.735	0.572	0.410
FTKN	mg/L		0.325	0.332	0.287	0.523	0.463	0.342	0.771
Ortho-P	mg/L		0.000	0.000	0.000	0.000	0.000	0.000	0.000
FTP	mg/L		0.000	0.000	0.000	0.000	0.000	0.000	0.000
TP	mg/L		0.069	0.080	0.070	0.067	0.053	0.076	0.111

Lacey Spring Branch
Trout Farm Outfall-Harvesting
Started harvesting at 9:35 a.m. and stopped by 10:10 a.m.

Code			1LSHR1	1LSHR2	1LSHR3	1LSHR4	1LSHR5	1LSHR6	1LSHR7	1LSHR8
Date			8/23/01	8/23/01	8/23/01	8/23/01	8/23/01	8/23/01	8/23/01	8/23/01
Time			9:50 AM	9:57 AM	10:02 AM	10:07 AM	10:12 AM	10:17 AM	10:27 AM	10:38 AM
Cond.	µS/cm	669								
Temp.	^{o}C	13.4								
pH		7.2								
DO	mg/L	6								
Alkalinity	mg/L		272	272	270	268	274	264	272	262
Hardness	mg/L		200	348	344	343	354	343	286	341
DOC	mg/L		1.25	1.20	1.11	1.13	1.84	1.40	1.32	1.42
TSS	mg/L		3.297	3.059	2.637	2.727	2.588	3.095	6.067	2.824
TDS	mg/L		337	402	321	405	414	328	371	410
SS	mL/L		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitrate	mg/L		5.296	5.253	5.176	5.325	5.392	5.319	5.336	5.296
Nitrite	mg/L		0.000	0.003	0.005	0.007	0.008	0.013	0.017	0.017
Ammonia	mg/L		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TKN	mg/L		1.973	0.625	0.509	0.397	0.635	0.657	0.584	0.898
FTKN	mg/L		0.179	0.423	0.262	0.554	0.422	0.586	0.309	0.459
Ortho-P	mg/L		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FTP	mg/L		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TP	mg/L		0.075	0.094	0.093	0.104	0.096	0.112	0.128	0.113

Lacey Spring Branch Side Stream			
Code		1LSSS1	2LSSS1
Date		8/23/01	1/26/02
Time		11:00 AM	9:55 AM
Cond.	µS/cm	657	410
Temp.	^{o}C	13.6	
pH		7.3	7.3
DO	mg/L	7	7
Alkalinity	mg/L	250	272
Hardness	mg/L	334	332
DOC	mg/L	1.31	0.88
TSS	mg/L	4.545	1.200
TDS	mg/L	306	409
SS	mL/L	0.0	0.1
Nitrate	mg/L	5.502	3.854
Nitrite	mg/L	0.016	0.013
Ammonia	mg/L	0.017	0.125
TKN	mg/L	0.000	0.282
FTKN	mg/L	0.000	0.000
Ortho-P	mg/L	0.000	0.009
FTP	mg/L	0.000	0.000
TP	mg/L	0.070	0.000

Lacey Spring Branch Benthic Sampling Site			
Code		1LSB1	2LSB1
Date		8/21/01	1/26/02
Time		12:30 PM	11:55 AM
Cond.	µS/cm	688	415
Temp.	^{o}C	13.9	13.3
pH		7.2	7.2
DO	mg/L	7	8
Alkalinity	mg/L	232	270
Hardness	mg/L	363	331
DOC	mg/L	0.62	0.59
TSS	mg/L	4.762	0.400
TDS	mg/L	324	412
SS	mL/L	0.0	0.0
Nitrate	mg/L	5.602	4.029
Nitrite	mg/L	0.000	0.000
Ammonia	mg/L	0.012	0.000
TKN	mg/L	0.673	0.000
FTKN	mg/L	0.246	0.000
Ortho-P	mg/L	0.000	0.000
FTP	mg/L	0.000	0.000
TP	mg/L	0.171	0.000

Lacey Spring Branch Near End of Impairment			
Code		1LSEI1	2LSEI1
Date		8/22/01	1/26/02
Time		1:50 PM	2:22 PM
Cond.	µS/cm	674	410
Temp.	^{o}C	14.3	13.3
pH		7.3	7.3
DO	mg/L	7	8
Alkalinity	mg/L	209	272
Hardness	mg/L	337	328
DOC	mg/L	1.29	0.87
TSS	mg/L	2.824	1.923
TDS	mg/L	308	414
SS	mL/L	0.0	0.0
Nitrate	mg/L	5.624	4.075
Nitrite	mg/L	0.016	0.003
Ammonia	mg/L	0.000	0.000
TKN	mg/L	0.000	0.000
FTKN	mg/L	0.000	0.000
Ortho-P	mg/L	0.000	0.009
FTP	mg/L	0.000	0.000
TP	mg/L	0.114	0.000

Water Sample Analysis Results for Orndorff Spring Branch

(See Appendix G for detection limits)

Orndorff Spring Branch
Headwaters
MS=Main Spring; SS=Secondary Spring; H=Headwaters of Trout Farm

Code		1OMS1	1OSS1	1OH1	2OH1	3OH1	4OH1	5OH1	6OH1	70H1
Date		7/23/01	7/23/01	7/23/01	7/24/01	7/24/01	7/27/01	7/27/01	7/28/01	1/26/02
Time		4:35 PM	5:10 PM	9:15 PM	7:38 AM	2:50 PM	8:55 AM	4:35 PM	1:55 PM	12:20 PM
Cond.	µS/cm	278	252	256	250	252	275	215	216	360
Temp.	^oC	13.6	13.5	13.9	13.7	14.7	13.6	13.8	13.8	13.1
pH		7.4	7.6	7.3	7.4	7.5	7.3	7.3	7.4	7.7
DO	mg/L	7	7	7	7	7	7	8	7	7
Alkalinity	mg/L	133	136	132	132	132	133	134	135	142
Hardness	mg/L	144	136	142	148	142	147	146	148	160
DOC	mg/L	1.34	3.34	1.61	1.76	3.13	0.59	0.41	0.65	0.70
TSS	mg/L	0.000	0.000	0.339	0.000	0.000	0.000	0.241	0.000	0.000
TDS	mg/L	185	175	181	184	184	180	183	184	176
SS	mL/L	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitrate	mg/L	0.242	0.300	0.257	0.253	0.251	0.279	0.284	0.292	0.230
Nitrite	mg/L	0.000	0.000	0.000	0.000	0.000	0.050	0.064	0.077	0.000
Ammonia	mg/L	0.013	0.013	0.013	0.092	0.013	0.013	0.020	0.013	0.004
TKN	mg/L	1.325	1.256	1.120	0.865	1.270	0.780	0.830	0.527	0.000
FTKN	mg/L	0.345	0.146	0.289	0.239	0.414	0.521	0.678	0.643	0.000
Ortho-P	mg/L	0.029	0.021	0.029	0.021	0.035	0.018	0.041	0.051	0.048
FTP	mg/L	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TP	mg/L	0.011	0.013	0.000	0.021	0.000	0.022	0.062	0.064	0.000

Orndorff Spring Branch
Wet-weather Spring Stream

Code		1OWWS	2OWWS	3OWWS
Date		7/23/01	7/24/01	1/26/02
Time		6:05 PM	9:07 AM	10:03 AM
Cond.	µS/cm	260	281	310
Temp.	^oC	22.2	18.8	1.7
PH		7.5	7.6	7.7
DO	mg/L	4	6	9
Alkalinity	mg/L	132	139	219
Hardness	mg/L	149	147	136
DOC	mg/L	5.07	2.54	1.17
TSS	mg/L	70.169	3.333	0.000
TDS	mg/L	176	187	170
SS	mL/L	0.4	0.0	0.1
Nitrate	mg/L	0.139	0.291	0.164
Nitrite	mg/L	0.001	0.000	0.000
Ammonia	mg/L	0.013	0.013	0.003
TKN	mg/L	0.813	1.115	0.005
FTKN	mg/L	0.876	0.581	0.000
Ortho-P	mg/L	0.014	0.019	0.003
FTP	mg/L	0.000	0.000	0.000
TP	mg/L	0.221	0.030	0.000

Orndorff Spring Branch
Benthic Sampling Site

Code		1OI1	2OI1
Date		7/23/01	1/26/02
Time		5:50 PM	10:35 AM
Cond.	µS/cm	240	360
Temp.	^oC	18.8	10.2
PH		7.7	7.8
DO	mg/L	7	7
Alkalinity	mg/L	135	141
Hardness	mg/L	148	158
DOC	mg/L	3.22	1.18
TSS	mg/L	0.000	1.600
TDS	mg/L	186	200
SS	mL/L	0.1	0.1
Nitrate	mg/L	0.268	0.322
Nitrite	mg/L	0.016	0.005
Ammonia	mg/L	0.068	0.726
TKN	mg/L	1.489	1.189
FTKN	mg/L	0.229	0.563
Ortho-P	mg/L	0.053	0.074
FTP	mg/L	0.011	0.000
TP	mg/L	0.101	0.000

Orndorff Spring Branch
Trout Farm Outfall, No Activity

Code		1ONA1	2ONA1	3ONA1	4ONA1	5ONA1	6ONA1	7ONA1
Date		7/23/01	7/24/01	7/24/01	7/27/01	7/27/01	7/28/01	1/26/02
Time		9:30 PM	7:21 AM	1:35 PM	7:05 AM	4:15 PM	2:28 PM	9:40 AM
Cond.	µS/cm	283	283	275	305	240	238	360
Temp.	^oC	16.1	14.4	18.2	14.1	17.9	15.5	10.3
pH		7.7	7.5	7.8	7.5	7.6	7.7	7.7
DO	mg/L	7	9	7	8	7	8	7
Alkalinity	mg/L	137	138	136	141	136	138	141
Hardness	mg/L	144	151	143	150	148	150	159
DOC	mg/L	1.96	1.36	2.97	0.72	1.17	0.77	1.39
TSS	mg/L	27.500	0.000	0.000	0.930	0.000	0.000	1.429
TDS	mg/L	191	192	189	189	185	186	201
SS	mL/L	0.1	0.0	0.0	0.1	0.0	0.0	0.1
Nitrate	mg/L	0.231	0.206	0.235	0.262	0.273	0.276	0.286
Nitrite	mg/L	0.000	0.000	0.000	0.055	0.071	0.085	0.002
Ammonia	mg/L	0.099	0.229	0.273	0.371	0.411	0.339	0.760
TKN	mg/L	1.856	1.804	2.478	1.696	2.361	1.762	1.030
FTKN	mg/L	0.418	0.516	0.549	0.617	0.569	0.682	0.675
Ortho-P	mg/L	0.050	0.062	0.083	0.067	0.061	0.091	0.072
FTP	mg/L	0.033	0.021	0.003	0.000	0.000	0.000	0.000
TP	mg/L	0.100	0.137	0.136	0.140	0.140	0.150	0.000

Orndorff Spring Branch								
Trout Farm Outfall, Pre-cleaning Feeding								
Started feeding at 7:53 a.m. and ended at 8:00 a.m. Automatic feeders in lower 3 raceways.								
Code			1OF1	1OF2	1OF3	1OF4	1OF5	1OF6
Date			7/24/01	7/24/01	7/24/01	7/24/01	7/24/01	7/24/01
Time			8:03 AM	8:08 AM	8:13 AM	8:23 AM	8:33 AM	8:43 AM
Cond.	µS/cm	276						
Temp.	^{o}C	14.7						
PH		7.6						
DO	mg/L	8						
Alkalinity	mg/L		139	137	136	136	137	137
Hardness	mg/L		149	149	147	146	152	148
DOC	mg/L		1.33	1.89	1.96	1.91	1.94	1.62
TSS	mg/L		0.667	0.000	0.000	0.000	0.000	0.370
TDS	mg/L		191	191	191	191	190	191
SS	mL/L		0.1	0.1	0.0	0.0	0.0	0.2
Nitrate	mg/L		0.233	0.238	0.226	0.232	0.230	0.237
Nitrite	mg/L		0.000	0.000	0.000	0.000	0.000	0.000
Ammonia	mg/L		0.189	0.128	0.136	0.098	0.073	0.093
TKN	mg/L		1.738	1.786	1.561	1.656	1.863	1.778
FTKN	mg/L		0.340	0.488	0.306	0.283	0.318	0.487
Ortho-P	mg/L		0.059	0.048	0.049	0.035	0.035	0.039
FTP	mg/L		0.000	1.601	0.036	0.197	0.030	0.007
TP	mg/L		0.155	0.086	0.098	0.115	0.112	0.103

Orndorff Spring Branch								
Trout Farm Outfall, Pre-cleaning Feeding								
Started feeding at 8:30 a.m. and ended at 8:40 a.m. Automatic feeders in lower 3 raceways.								
Code			2OF1	2OF2	2OF3	2OF4	2OF5	2OF6
Date			7/25/2001	7/25/2001	7/25/2001	7/25/2001	7/25/2001	7/25/2001
Time			8:40 AM	8:45 AM	8:50 AM	8:55 AM	9:05 AM	9:15 AM
Cond.	µS/cm	296						
Temp.	^{o}C	15.2						
pH		7.7						
DO	mg/L	7						
Alkalinity	mg/L		137	137	136	136	137	136
Hardness	mg/L		151	150	150	150	151	152
DOC	mg/L		2.56	2.73	2.52	2.28	2.21	2.27
TSS	mg/L		0.690	0.000	0.678	0.345	0.000	0.000
TDS	mg/L		193	193	192	192	193	193
SS	mL/L		0.1	0.1	0.1	0.1	0.0	0.4
Nitrate	mg/L		0.248	0.250	0.252	0.241	0.250	0.247
Nitrite	mg/L		0.017	0.019	0.022	0.022	0.025	0.026
Ammonia	mg/L		0.241	0.214	0.236	0.438	0.315	0.300
TKN	mg/L		1.399	2.312	1.525	1.701	1.931	1.435
FTKN	mg/L		0.363	1.097	0.503	0.286	0.519	0.304
Ortho-P	mg/L		0.084	0.081	0.068	0.093	0.083	0.075
FTP	mg/L		0.000	0.000	0.088	0.000	0.000	0.000
TP	mg/L		0.183	0.147	0.186	0.172	0.185	0.192

Orndorff Spring Branch								
Trout Farm Outfall, Post-cleaning Feeding								
Started feeding at 7:24 a.m. and ended 7:34 a.m. Automatic feeders in lower 3 raceways.								
Code			3OF1	3OF2	3OF3	3OF4	3OF5	3OF6
Date			7/27/01	7/27/01	7/27/01	7/27/01	7/27/01	7/27/01
Time			7:32 AM	7:38 AM	7:45 AM	7:50 AM	8:00 AM	8:15 AM
Cond.	µS/cm	304						
Temp.	^{o}C	14.1						
pH		7.5						
DO	mg/L	7						
Alkalinity	mg/L		140	139	138	139	139	139
Hardness	mg/L		157	153	152	152	151	151
DOC	mg/L		0.68	0.71	1.00	0.82	0.86	0.96
TSS	mg/L		0.976	1.500	1.463	1.190	1.282	0.482
TDS	mg/L		189	188	189	188	188	188
SS	mL/L		0.1	0.1	0.1	0.1	0.1	0.1
Nitrate	mg/L		0.271	0.267	0.267	0.271	0.268	0.267
Nitrite	mg/L		0.054	0.056	0.054	0.054	0.056	0.056
Ammonia	mg/L		0.407	0.343	0.315	0.332	0.302	0.330
TKN	mg/L		1.604	1.509	1.446	1.590	1.772	1.830
FTKN	mg/L		0.684	0.554	0.605	0.471	0.566	0.827
Ortho-P	mg/L		0.061	0.055	0.057	0.055	0.056	0.057
FTP	mg/L		0.000	0.000	0.000	0.000	0.000	0.000
TP	mg/L		0.186	0.179	0.200	0.134	0.101	0.157

Orndorff Spring Branch								
Trout Farm Outfall, Post-cleaning Feeding								
Started feeding at 4:40 p.m. and ended at 4:55 p.m. Automatic feeders in lower 3 raceways.								
Code			4OF1	4OF2	4OF3	4OF4	4OF5	4OF6
Date			7/27/2001	7/27/2001	7/27/2001	7/27/2001	7/27/2001	7/27/2001
Time			4:45 PM	4:50 PM	4:55 PM	5:00 PM	5:10 PM	5:20 PM
Cond.	µS/cm	240						
Temp.	^{o}C	17.9						
pH		7.6						
DO	mg/L	7						
Alkalinity	mg/L		136	136	138	136	136	138
Hardness	mg/L		155	152	152	150	147	150
DOC	mg/L		0.77	0.90	0.98	0.86	0.87	0.81
TSS	mg/L		0.000	0.723	1.190	2.045	0.920	0.235
TDS	mg/L		186	188	187	187	187	187
SS	mL/L		0.1	0.1	0.1	0.0	0.1	0.1
Nitrate	mg/L		0.276	0.273	0.276	0.281	0.276	0.278
Nitrite	mg/L		0.073	0.071	0.076	0.079	0.080	0.082
Ammonia	mg/L		0.398	0.409	0.439	0.526	0.447	0.455
TKN	mg/L		2.333	2.043	1.974	2.294	1.998	2.055
FTKN	mg/L		0.824	0.853	1.184	0.566	0.848	0.840
Ortho-P	mg/L		0.071	0.074	0.072	0.084	0.079	0.081
FTP	mg/L		0.000	0.000	0.000	0.000	0.000	0.000
TP	mg/L		0.170	0.178	0.165	0.220	0.161	0.176

Orndorff Spring Branch										
Trout Farm Outfall, Pre-cleaning Harvest										
Harvested 400 lbs. Began harvesting at 7:15 a.m. and ended at 8:05 a.m. Took break at 7:40 a.m.										
Code			1OHR1	1OHR2	1OHR3	1OHR4	1OHR5	1OHR6	1OHR7	1OHR8
Date			7/25/01	7/25/01	7/25/01	7/25/01	7/25/01	7/25/01	7/25/01	7/25/01
Time			7:15 AM	7:22 AM	7:30 AM	7:35 AM	7:50 AM	7:55 AM	8:07 AM	8:20 AM
Cond.	µS/cm	276								
Temp.	^{o}C	14.8								
pH		7.7								
DO	mg/L	7								
Alkalinity	mg/L		136	136	138	138	138	137	138	137
Hardness	mg/L		152	152	152	153	151	152	153	150
DOC	mg/L		2.92	2.60	2.74	2.59	2.81	2.81	2.56	2.50
TSS	mg/L		1.270	0.000	0.351	0.303	1.270	1.034	2.000	13.333
TDS	mg/L		192	191	191	192	193	193	193	194
SS	mL/L		0.1	0.0	0.1	0.1	0.1	0.1	0.0	0.1
Nitrate	mg/L		0.242	0.239	0.237	0.239	0.241	0.250	0.250	0.249
Nitrite	mg/L		0.001	0.001	0.002	0.005	0.007	0.008	0.012	0.018
Ammonia	mg/L		0.239	0.223	0.205	0.204	0.263	0.209	0.298	0.255
TKN	mg/L		1.556	1.407	1.509	1.300	1.395	1.471	1.507	1.386
FTKN	mg/L		0.376	0.472	0.678	1.050	0.515	0.428	0.414	0.490
Ortho-P	mg/L		0.072	0.076	0.079	0.077	0.089	0.082	0.095	0.089
FTP	mg/L		0.038	0.000	0.056	0.022	0.000	0.000	0.000	0.000
TP	mg/L		0.107	0.100	0.186	0.180	0.222	0.238	0.185	0.353

Orndorff Spring Branch									
Trout Farm Outfall, Post-Cleaning Harvest									
Began harvesting at 10:00 a.m. and ended at 10:15 a.m.									
Code			2OHR1	2OHR2	2OHR3	2OHR4	2OHR5	2OHR6	2OHR7
Date			7/27/01	7/27/01	7/27/01	7/27/01	7/27/01	7/27/01	7/27/01
Time			9:55 AM	10:08 AM	10:18 AM	10:24 AM	10:30 AM	10:34 AM	10:45 AM
Cond.	µS/cm	203							
Temp.	^{o}C	14.5							
pH		7.8							
DO	mg/L	9							
Alkalinity	mg/L		138	138	140	139	139	139	138
Hardness	mg/L		150	148	152	150	151	151	151
DOC	mg/L		0.85	0.86	1.17	1.34	0.86	0.84	0.96
TSS	mg/L		8.293	3.023	3.371	4.235	3.614	5.977	5.111
TDS	mg/L		188	186	187	187	189	188	187
SS	mL/L		0.0	0.2	0.1	0.0	0.2	0.2	0.2
Nitrate	mg/L		0.270	0.267	0.271	0.269	0.273	0.277	0.274
Nitrite	mg/L		0.057	0.058	0.058	0.065	0.063	0.064	0.066
Ammonia	mg/L		0.416	0.385	0.391	0.371	0.391	0.381	0.407
TKN	mg/L		1.707	1.648	1.772	1.873	1.682	1.964	1.809
FTKN	mg/L		0.542	0.627	0.784	0.719	0.906	0.678	0.888
Ortho-P	mg/L		0.046	0.058	0.068	0.072	0.079	0.075	0.081
FTP	mg/L		0.000	0.000	0.000	0.000	0.000	0.000	0.000
TP	mg/L		0.128	0.176	0.179	0.165	0.249	0.193	0.163

Orndorff Spring Branch

Trout Farm Outfall, Cleaning Sediment Traps

Started cleaning lowermost trap at 7:18 a.m. Started cleaning middle trap at 8:04 a.m. and ended at 8:12 a.m. Started cleaning uppermost trap at 8:19 a.m. and ended at 8:29 a.m.

Code			1OC1	1OC2	1OC3	1OC4	1OC5	1OC6	1OC7	1OC8	1OC9
Date			7/26/01	7/26/01	7/26/01	7/26/01	7/26/01	7/26/01	7/26/01	7/26/01	7/26/01
Time			7:18 AM	7:32 AM	7:36 AM	7:43 AM	8:05 AM	8:14 AM	8:29 AM	8:35 AM	8:40 AM
Cond.	µS/cm	273									
Temp.	^{o}C	14.8									
pH		7.7									
DO	mg/L	7									
Alkalinity	mg/L		138	137	138	138	140	140	139	138	139
Hardness	mg/L		151	147	150	150	158	152	150	149	149
DOC	mg/L		0.69	0.68	0.75	0.73	0.61	0.59	0.71	0.67	0.74
TSS	mg/L		0.471	1.975	1.412	0.698	0.000	0.000	0.000	0.000	0.471
TDS	mg/L		189	188	189	189	189	188	189	187	188
SS	mL/L		0.0	0.2	0.1	0.1	0.0	0.0	0.1	0.1	0.1
Nitrate	mg/L		0.244	0.259	0.260	0.253	0.259	0.261	0.263	0.262	0.266
Nitrite	mg/L		0.055	0.054	0.053	0.053	0.053	0.053	0.054	0.054	0.054
Ammonia	mg/L		0.446	0.361	0.343	0.401	0.338	0.349	0.346	0.386	0.376
TKN	mg/L		1.445	1.376	1.216	1.629	1.809	1.619	1.481	1.561	1.671
FTKN	mg/L		0.495	0.533	0.491	0.414	0.442	0.396	0.419	0.544	0.364
Ortho-P	mg/L		0.082	0.082	0.084	0.091	0.077	0.079	0.068	0.071	0.077
FTP	mg/L		0.000	0.000	0.067	0.000	0.000	0.000	0.000	0.000	0.000
TP	mg/L		0.257	0.266	0.373	0.378	0.170	0.157	0.143	0.139	0.193

Water Sample Analysis Results for Pheasanty Run

(See Appendix G for detection limits)

Pheasanty Run Upstream Site					
Code		1PU1	2PU1	3PU1	4PU1
Date		8/1/2001	9/20/2001	9/23/2001	1/31/2002
Time		1:00 PM	1:00 PM	3:55 PM	12:50 PM
Cond.	µS/cm	201	243	248	120
Temp.	^{o}C	20.9	17.4	20.5	10.1
pH		7.5	7.4	7.6	7.6
DO	mg/L	7	7	7	7
Alkalinity	mg/L	101	114	115	84
Hardness	mg/L	111	123	126	94
DOC	mg/L	2.39	2.07	2.29	1.94
TSS	mg/L	18.421	19.259	6.747	35.111
TDS	mg/L	136	168	171	120
SS	mL/L	0.1	0.3	0.1	0.1
Nitrate	mg/L	0.182	0.038	0.030	0.084
Nitrite	mg/L	0.069	0.000	0.000	0.000
Ammonia	mg/L	0.050	0.000	0.000	0.003
TKN	mg/L	0.800	0.415	0.230	0.108
FTKN	mg/L	0.579	0.067	0.000	0.000
Ortho-P	mg/L	0.029	0.000	0.000	0.005
FTP	mg/L	0.000	0.000	0.000	0.000
TP	mg/L	0.038	0.148	0.100	0.000

Pheasanty Run Headwaters of Trout Farm (Coursey Springs)					
Code		1PH1	2PH1	3PH1	4PH1
Date		8/1/01	9/20/01	9/23/01	1/31/02
Time		1:57 PM	2:45 PM	1:37 PM	12:27 PM
Cond.	µS/cm	175	242	250	100
Temp.	^{o}C	14.1	14.3	15.1	11.3
pH		8.1	7.7	8.0	7.9
DO	mg/L	8	8	9	8
Alkalinity	mg/L	79	104	106	56
Hardness	mg/L	94	122	125	72
DOC	mg/L	1.44	0.75	1.53	0.94
TSS	mg/L	0.000	0.000	0.000	0.000
TDS	mg/L	121	172	157	100
SS	mL/L	0.0	0.0	0.0	0.0
Nitrate	mg/L	0.366	0.272	0.229	0.271
Nitrite	mg/L	0.068	0.000	0.000	0.000
Ammonia	mg/L	0.066	0.000	0.000	0.000
TKN	mg/L	0.651	0.059	0.007	0.000
FTKN	mg/L	0.582	0.000	0.000	0.000
Ortho-P	mg/L	0.038	0.000	0.000	0.000
FTP	mg/L	0.000	0.000	0.000	0.000
TP	mg/L	0.012	0.095	0.067	0.000

Pheasanty Run				
Spring Run, Upstream Site				
9/20/01 Very low flow; disturbed bottom when sampling				
Code		1PSRU1	2PSRU1	3PSRU1
Date		8/1/2001	9/20/2001	9/23/2001
Time		2:15 PM	3:00 PM	2:05 PM
Cond.	µS/cm	175	244	207
Temp.	^{o}C	15.3	19.3	23.7
pH		8.4	8.6	9.2
DO	mg/L	9	8	12
Alkalinity	mg/L	81	109	87
Hardness	mg/L	95	124	102
DOC	mg/L	1.59	1.56	1.57
TSS	mg/L	0.000	48.293	2.439
TDS	mg/L	123	177	142
SS	mL/L	0.0	0.0	0.1
Nitrate	mg/L	0.401	0.170	0.015
Nitrite	mg/L	0.070	0.000	0.000
Ammonia	mg/L	0.045	0.000	0.000
TKN	mg/L	0.639	0.280	0.620
FTKN	mg/L	0.656	0.221	0.008
Ortho-P	mg/L	0.040	0.000	0.000
FTP	mg/L	0.000	0.000	0.000
TP	mg/L	0.019	0.226	0.173

Pheasanty Run					
Spring Run, Downstream Site					
9/20/01 and 9/23/01--Water mostly standing; flowing only in middle					
Code		1PSRD1	2PSRD1	3PSRD1	4PSRD1
Date		8/1/01	9/20/01	9/23/01	1/31/02
Time		1:30 PM	3:53 AM	3:35 AM	5:07 PM
Cond.	µS/cm	178	243	246	100
Temp.	^{o}C	15.1	15.7	19.0	12.0
pH		8.6	7.6	8.1	8.0
DO	mg/L	9	8	9	7
Alkalinity	mg/L	81	106	104	60
Hardness	mg/L	98	119	121	76
DOC	mg/L	1.38	1.91	1.04	1.08
TSS	mg/L	7.619	1.951	1.839	3.505
TDS	mg/L	124	172	167	101
SS	mL/L	0.1	0.1	0.1	0.1
Nitrate	mg/L	0.368	0.265	0.237	0.274
Nitrite	mg/L	0.076	0.000	0.000	0.000
Ammonia	mg/L	0.041	0.000	0.000	0.000
TKN	mg/L	0.701	0.291	0.619	0.000
FTKN	mg/L	0.572	0.000	0.000	0.000
Ortho-P	mg/L	0.048	0.000	0.000	0.000
FTP	mg/L	0.000	0.000	0.000	0.000
TP	mg/L	0.135	0.175	0.067	0.000

Pheasanty Run Pipe Discharge				
Code		1PPD1	2PPD1	3PPD1
Date		8/1/01	9/20/01	9/23/01
Time		1:15 PM	3:30 PM	3:10 PM
Cond.	µS/cm	182	243	251
Temp.	^oC	15.1	15.0	17.3
pH		7.8	7.5	7.7
DO	mg/L	7	6	7
Alkalinity	mg/L	82	103	106
Hardness	mg/L	93	121	126
DOC	mg/L	1.50	1.15	0.98
TSS	mg/L	2.697	3.596	3.294
TDS	mg/L	123	168	167
SS	mL/L	0.0	0.1	0.1
Nitrate	mg/L	0.422	0.248	0.228
Nitrite	mg/L	0.078	0.000	0.000
Ammonia	mg/L	0.093	0.000	0.000
TKN	mg/L	1.162	0.424	0.478
FTKN	mg/L	0.605	0.000	0.000
Ortho-P	mg/L	0.045	0.000	0.000
FTP	mg/L	0.000	0.000	0.000
TP	mg/L	0.025	0.209	0.091

Pheasanty Run Trout Farm Outfall						
Code		3PTDA	3PTDB	3PTDC	4PTDA	4PTDB
Date		9/23/01	9/23/01	9/23/01	1/31/02	1/31/02
Time		4:22 PM	4:36 PM	4:50 PM	5:20 PM	5:30 PM
Cond.	µS/cm	251	254	254	110	110
Temp.	^oC	18.3	17.9	17.2	12.5	12.0
pH		7.5	7.5	7.6	7.5	7.3
DO	mg/L	6	6		8	8
Alkalinity	mg/L	107	108	108	59	58
Hardness	mg/L	121	124	124	73	74
DOC	mg/L	1.24	1.27	1.20	1.44	1.24
TSS	mg/L	1.905	0.460	9.487	3.191	4.130
TDS	mg/L	168	172	155	102	102
SS	mL/L	0.0	0.1	0.1	0.1	0.1
Nitrate	mg/L	0.189	0.248	0.215	0.280	0.286
Nitrite	mg/L	0.000	0.000	0.000	0.000	0.000
Ammonia	mg/L	0.019	0.010	0.050	0.421	0.210
TKN	mg/L	0.794	0.711	0.498	0.535	0.218
FTKN	mg/L	0.000	0.018	0.000	0.155	0.000
Ortho-P	mg/L	0.000	0.000	0.000	0.000	0.000
FTP	mg/L	0.000	0.000	0.000	0.000	0.000
TP	mg/L	0.114	0.115	0.088	0.000	0.000

Pheasanty Run Near End of Impairment					
Code		1PEI1	2PEI1	3PEI1	4PEI1
Date		8/1/01	9/20/01	9/23/01	1/31/02
Time		3:55 PM	5:40 PM	6:15 PM	2:45 PM
Cond.	µS/cm	178	244	251	110
Temp.	^{o}C	17.6	16.0	18.3	13.2
pH		8.6	7.7	7.7	7.8
DO	mg/L	10	8	7	9
Alkalinity	mg/L	80	105	107	58
Hardness	mg/L	93	120	123	75
DOC	mg/L	1.55	0.93	1.12	1.54
TSS	mg/L	1.538	2.299	2.273	3.137
TDS	mg/L	124	170	170	105
SS	mL/L	0.0	0.1	0.1	0.1
Nitrate	mg/L	0.772	0.286	0.255	0.268
Nitrite	mg/L	0.089	0.000	0.000	0.012
Ammonia	mg/L	0.185	0.000	0.000	0.231
TKN	mg/L	1.821	0.350	0.565	0.187
FTKN	mg/L	0.648	0.000	0.000	0.000
Ortho-P	mg/L	0.047	0.006	0.000	0.000
FTP	mg/L	0.000	0.000	0.000	0.000
TP	mg/L	0.026	0.119	0.082	0.000

Water Sample Analysis Results for Wallace Mill Stream

(See Appendix G for detection limits)

Wallace Mill Stream Headwaters					
Code		1WMH1	2WMH1	3WMH1	4WMH1
Date		8/8/01	8/8/01	8/9/01	2/2/02
Time		6:44 PM	9:18 PM	1:35 PM	3:40 PM
Cond.	µS/cm	213	211	216	150
Temp.	^{o}C	14.7	14.5	14.8	13.5
pH		7.7	7.6	7.5	7.8
DO	mg/L	7	7	7	7
Alkalinity	mg/L	95	96	96	100
Hardness	mg/L	105	106	104	111
DOC	mg/L	0.53	0.33	0.50	0.81
TSS	mg/L	0.000	0.000	0.000	0.000
TDS	mg/L	130	129	128	137
SS	mL/L	0.0	0.0	0.0	0.0
Nitrate	mg/L	0.074	0.068	0.062	0.023
Nitrite	mg/L	0.000	0.000	0.000	0.000
Ammonia	mg/L	0.000	0.000	0.000	0.000
TKN	mg/L	0.538	0.389	0.591	0.000
FTKN	mg/L	0.365	0.319	0.448	0.000
Ortho-P	mg/L	0.000	0.000	0.000	0.012
FTP	mg/L	0.000	0.000	0.000	0.000
TP	mg/L	0.000	0.000	0.000	0.000

Wallace Mill Stream Trout Farm Outfall-No Activity					
Code		1WMNA1	2WMNA1	3WMNA1	4WMNA1
Date		8/8/01	8/8/01	8/9/01	2/2/02
Time		6:25 PM	9:05 PM	2:00 PM	2:34 PM
Cond.	µS/cm	229	227	233	150
Temp.	^{o}C	18.6	17.4	19.2	11.1
pH		7.5	7.4	7.3	7.5
DO	mg/L	4	5	4	7
Alkalinity	mg/L	94	94	96	100
Hardness	mg/L	104	104	104	114
DOC	mg/L	1.06	1.08	1.23	2.18
TSS	mg/L	19.059	0.000	0.000	3.789
TDS	mg/L	136	136	134	150
SS	mL/L	0.0	0.0	0.0	0.0
Nitrate	mg/L	1.021	1.034	1.016	1.072
Nitrite	mg/L	0.065	0.058	0.081	0.057
Ammonia	mg/L	0.708	0.620	0.761	0.673
TKN	mg/L	2.574	2.500	2.245	1.154
FTKN	mg/L	0.612	0.700	0.687	0.563
Ortho-P	mg/L	0.069	0.068	0.074	0.094
FTP	mg/L	0.000	0.000	0.000	0.000
TP	mg/L	0.160	0.136	0.172	0.000

Wallace Mill Stream							
Trout Farm Outfall Upper Raceways, Feeding							
Started at 8:30 a.m. and stopped at 9:10 a.m. Mostly use automatic feeders.							
Code			1WMF1	1WMF2	1WMF3	1WMF4	1WMF5
Date			8/9/01	8/9/01	8/9/01	8/9/01	8/9/01
Time			8:36 AM	8:41 AM	8:52 AM	9:02 AM	9:26 AM
Cond.	µS/cm	217					
Temp.	^{o}C	15					
pH		7.6					
DO	mg/L						
Alkalinity	mg/L		94	97	96	97	98
Hardness	mg/L		105	105	105	108	108
DOC	mg/L		0.69	0.74	0.72	0.79	0.68
TSS	mg/L		18.864	0.000	0.000	0.000	0.000
TDS	mg/L		132	132	132	132	132
SS	mL/L		0.1	0.0	0.0	0.0	0.0
Nitrate	mg/L		0.298	0.140	0.144	0.137	0.135
Nitrite	mg/L		0.013	0.001	0.003	0.003	0.005
Ammonia	mg/L		0.423	0.450	0.465	0.435	0.409
TKN	mg/L		1.131	1.375	1.372	1.544	1.375
FTKN	mg/L		0.762	0.729	0.486	0.639	0.558
Ortho-P	mg/L		0.035	0.028	0.029	0.028	0.024
FTP	mg/L		0.000	0.000	0.000	0.000	0.000
TP	mg/L		0.246	0.067	0.066	0.066	0.067

Wallace Mill Stream							
Trout Farm Outfall Lower Raceways, Feeding							
Started at 8:45 a.m. and stopped at 9:00 a.m. Mostly use automatic feeders							
Code			1WMF6	1WMF7	1WMF8	1WMF9	1WMF10
Date			8/9/01	8/9/01	8/9/01	8/9/01	8/9/01
Time			9:00 AM	9:05 AM	9:08 AM	9:14 AM	9:20 AM
Cond.	µS/cm	226					
Temp.	^{o}C	16					
pH		7.4					
DO	mg/L	4.5					
Alkalinity	mg/L		94	94	95	95	95
Hardness	mg/L		108	107	107	106	105
DOC	mg/L		0.95	1.02	1.11	1.10	1.06
TSS	mg/L		1.096	0.000	0.476	0.000	0.260
TDS	mg/L		136	136	136	136	137
SS	mL/L		0.0	0.1	0.0	0.1	0.1
Nitrate	mg/L		0.979	0.996	0.099	0.981	0.986
Nitrite	mg/L		0.054	0.055	0.051	0.051	0.052
Ammonia	mg/L		0.542	0.525	0.599	0.633	0.672
TKN	mg/L		1.450	2.037	1.766	1.922	1.745
FTKN	mg/L		1.166	0.675	0.887	0.696	0.767
Ortho-P	mg/L		0.066	0.061	0.066	0.071	0.068
FTP	mg/L		0.000	0.000	0.000	0.000	0.000
TP	mg/L		0.175	0.172	0.134	0.136	0.154

Wallace Mill Stream

Trout Farm Outfall Lower Raceways, Feeding

Started at 7:28 p.m. and ended at 7:45 p.m. Mostly use automatic feeders.

Code			2WMF1	2WMF2	2WMF3	2WMF4	2WMF5	2WMF6
Date			8/9/01	8/9/01	8/9/01	8/9/01	8/9/01	8/9/01
Time			7:33 PM	7:37 PM	7:43 PM	7:48 PM	7:58 PM	8:08 PM
Cond.	µS/cm	231						
Temp.	^{o}C	17.9						
pH		7.3						
DO	mg/L	3.5						
Alkalinity	mg/L		94	94	94	94	94	95
Hardness	mg/L		107	106	107	106	108	107
DOC	mg/L		1.30	1.49	1.62	1.26	1.71	1.19
TSS	mg/L		0.465	0.238	0.465	0.465	0.000	2.222
TDS	mg/L		137	138	138	138	138	138
SS	mL/L		0.1	0.0	0.0	0.0	0.0	0.0
Nitrate	mg/L		1.239	1.221	1.216	1.217	1.221	1.190
Nitrite	mg/L		0.110	0.105	0.106	0.106	0.113	0.114
Ammonia	mg/L		0.808	0.842	0.804	0.827	0.819	0.813
TKN	mg/L		2.224	1.925	2.011	2.098	2.407	1.796
FTKN	mg/L		0.778	0.795	0.957	0.781	0.910	1.035
Ortho-P	mg/L		0.074	0.072	0.065	0.066	0.074	0.089
FTP	mg/L		0.000	0.000	0.000	0.000	0.000	0.000
TP	mg/L		0.191	0.202	0.261	0.196	0.216	0.209

Wallace Mill Stream					
Trout Farm Outfall Upper Raceways, Feeding					
Started at 8:30 a.m. and stopped at 9:05 a.m.					
Code			3WMF1	3WMF2	3WMF3
Date			8/10/01	8/10/01	8/10/01
Time			8:48 AM	9:01 AM	9:09 AM
Cond.	µS/cm	218			
Temp.	^{o}C	15.1			
pH		7.5			
DO	mg/L				
Alkalinity	mg/L		98	99	98
Hardness	mg/L		107	105	106
DOC	mg/L		1.01	0.99	0.88
TSS	mg/L		0.465	0.000	0.000
TDS	mg/L		134	133	134
SS	mL/L		0.0	0.0	0.0
Nitrate	mg/L		0.153	0.139	0.139
Nitrite	mg/L		0.007	0.009	0.007
Ammonia	mg/L		0.621	0.611	0.596
TKN	mg/L		2.376	2.246	2.034
FTKN	mg/L		1.020	0.848	0.778
Ortho-P	mg/L		0.045	0.047	0.054
FTP	mg/L		0.000	0.000	0.000
TP	mg/L		0.241	0.130	0.110

Wallace Mill Stream									
Trout Farm Outfall Lower Raceways, Feeding									
3WMF7-Collected two clumps of solid particles (uneaten food?); not used in average.									
Code			3WMF4	3WMF5	3WMF6	3WMF7	3WMF8	3WMF9	3WMF10
Date			8/10/01	8/10/01	8/10/01	8/10/2001	8/10/2001	8/10/2001	8/10/2001
Time			8:15 AM	8:20 AM	8:25 AM	8:30 AM	8:35 AM	8:45 AM	8:55 AM
Cond.	µS/cm	228							
Temp.	^{o}C	15.8							
pH		7.4							
DO	mg/L	5.5							
Alkalinity	mg/L		95	93	95	116	93	95	94
Hardness	mg/L		107	108	105	136	109	108	108
DOC	mg/L		1.49	1.24	1.34	4.26	1.31	1.22	1.57
TSS	mg/L		1.647	1.333	1.163	370.500	0.674	0.000	6.744
TDS	mg/L		136	137	136	174	137	137	137
SS	mL/L		0.0	0.3	0.1	2.0	0.0	0.0	0.0
Nitrate	mg/L		1.134	1.139	1.109	0.053	1.117	1.112	1.103
Nitrite	mg/L		0.088	0.090	0.090	0.000	0.085	0.086	0.088
Ammonia	mg/L		0.640	0.686	0.719	1.464	0.657	0.643	0.638
TKN	mg/L		1.710	1.438	1.707	33.736	1.831	1.530	1.477
FTKN	mg/L		1.269	0.813	0.804	3.794	1.339	0.637	0.921
Ortho-P	mg/L		0.081	0.084	0.087	2.695	0.127	0.103	0.090
FTP	mg/L		0.000	0.000	0.000	5.819	0.000	0.000	0.000
TP	mg/L		0.172	0.235	0.208	12.194	0.410	0.285	0.229

Wallace Mill Stream							
Trout Farm Outfall Upper Raceways, Harvesting							
Simulated harvest in third raceway from end. Stopped harvesting at 10:37 a.m.							
Code			1WMHR1	1WMHR2	1WMHR3	1WMHR4	1WMHR5
Date			8/9/01	8/9/01	8/9/01	8/9/01	8/9/01
Time			10:34 AM	10:40 AM	10:45 AM	10:50 AM	11:01 AM
Cond.	µS/cm	218					
Temp.	^{o}C	15.5					
pH		7.4					
DO	mg/L						
Alkalinity	mg/L		98	98	97	98	98
Hardness	mg/L		106	105	106	105	106
DOC	mg/L		0.99	0.78	1.06	0.87	0.93
TSS	mg/L		0.000	0.000	0.000	0.000	0.230
TDS	mg/L		135	134	134	134	134
SS	mL/L		0.0	0.0	0.0	0.0	0.0
Nitrate	mg/L		0.122	0.119	0.115	0.109	0.112
Nitrite	mg/L		0.006	0.005	0.007	0.002	0.006
Ammonia	mg/L		0.537	0.512	0.511	0.580	0.560
TKN	mg/L		1.702	1.914	1.511	1.783	1.847
FTKN	mg/L		0.826	0.691	0.758	0.681	0.744
Ortho-P	mg/L		0.065	0.053	0.062	0.067	0.062
FTP	mg/L		0.000	0.000	0.000	0.000	0.000
TP	mg/L		0.131	0.219	0.192	0.160	0.136

Wallace Mill Stream								
Trout Farm Outfall Lower Raceways, Harvesting								
Simulated harvest in third raceway from end of upper series.								
Code			1WMHR6	1WMHR7	1WMHR8	1WMHR9	1WMHR10	1WMHR11
Date			8/9/01	8/9/01	8/9/01	8/9/01	8/9/01	8/9/01
Time			11:02 AM	11:08 AM	11:13 AM	11:18 AM	11:26 AM	11:36 AM
Cond.	µS/cm	232						
Temp.	^{o}C	16.7						
pH		7.4						
DO	mg/L	4.5						
Alkalinity	mg/L		94	94	93	93	92	92
Hardness	mg/L		106	106	105	106	106	105
DOC	mg/L		1.15	1.09	1.15	1.04	0.90	1.14
TSS	mg/L		0.000	0.000	0.455	0.000	0.000	0.000
TDS	mg/L		136	135	135	134	135	136
SS	mL/L		0.0	0.0	0.0	0.0	0.0	0.0
Nitrate	mg/L		0.936	0.946	0.957	0.959	0.960	0.953
Nitrite	mg/L		0.064	0.065	0.067	0.069	0.073	0.073
Ammonia	mg/L		0.579	0.592	0.535	0.559	0.522	0.525
TKN	mg/L		1.391	1.743	1.629	1.471	1.550	1.636
FTKN	mg/L		0.923	0.954	0.984	0.779	0.745	0.906
Ortho-P	mg/L		0.079	0.082	0.086	0.084	0.080	0.082
FTP	mg/L		0.000	0.000	0.000	0.000	0.000	0.000
TP	mg/L		0.173	0.182	0.180	0.174	0.164	0.162

Wallace Mill Stream						
Trout Farm End of Raceway, Sediment Trap Cleaning						
Started cleaning at 10:24 a.m. and stopped at 10:50 a.m.						
Code		1WMC1	1WMC2	1WMC3	1WMC4	1WMC5
Date		8/10/01	8/10/01	8/10/01	8/10/01	8/10/01
Time		10:25 AM	10:30 AM	10:35 AM	10:40 AM	10:45 AM
Cond.	µS/cm					
Temp.	^{o}C					
pH						
DO	mg/L					
Alkalinity	mg/L	91	92	92	91	91
Hardness	mg/L	105	112	108	109	108
DOC	mg/L	0.91	0.82	0.79	0.73	1.02
TSS	mg/L	10.115	0.706	0.674	0.460	0.941
TDS	mg/L	136	134	134	134	134
SS	mL/L	0.1	no sample	0.0	no sample	0.1
Nitrate	mg/L	1.087	1.077	1.059	1.060	1.086
Nitrite	mg/L	0.094	0.080	0.077	0.077	0.083
Ammonia	mg/L	0.305	0.365	0.363	0.427	0.378
TKN	mg/L	0.891	0.951	0.919	1.098	1.146
FTKN	mg/L	1.326	0.958	0.738	0.731	0.842
Ortho-P	mg/L	0.087	0.088	0.084	0.077	0.076
FTP	mg/L	0.000	0.000	0.000	0.000	0.000
TP	mg/L	0.283	0.130	0.145	0.154	0.155

Wallace Mill Stream								
Taken from confluence of side stream & trout farm outfall after cleaning a sediment trap.								
Code			1WMC7	1WMC8	1WMC9	1WMC10	1WMC11	1WMC12
Date			8/10/01	8/10/01	8/10/01	8/10/01	8/10/01	8/10/01
Time			11:00 AM	11:05 AM	11:15 AM	11:22 AM	11:30 AM	11:40 AM
Cond.	µS/cm	232						
Temp.	^{o}C	17.4						
pH		7.5						
DO	mg/L	7						
Alkalinity	mg/L		93	92	93	94	94	93
Hardness	mg/L		110	108	108	109	111	108
DOC	mg/L		1.45	1.12	1.24	1.13	1.78	1.52
TSS	mg/L		5.000	2.045	4.146	3.678	3.596	1.379
TDS	mg/L		139	137	138	139	138	139
SS	mL/L		0.1	no sample	0.1	no sample	0.1	no sample
Nitrate	mg/L		1.182	1.183	1.154	1.131	1.109	1.109
Nitrite	mg/L		0.097	0.099	0.100	0.103	0.103	0.105
Ammonia	mg/L		0.536	0.589	0.565	0.558	0.567	0.592
TKN	mg/L		1.349	1.356	1.377	1.828	1.452	1.682
FTKN	mg/L		0.997	1.246	1.360	0.777	1.151	1.427
Ortho-P	mg/L		0.090	0.095	0.096	0.121	0.187	0.214
FTP	mg/L		0.000	0.000	0.000	0.000	0.000	0.000
TP	mg/L		0.236	0.253	0.215	0.308	0.310	0.369

Wallace Mill Stream

BLR=Beginning Lower Raceway Series; UES=Upper Entering Stream (Side Stream);

PO=Pond Outfall (2/2/02 low water; disturbed bottom when sampling)

		Lower Raceways		**Side Stream**		**Pond Outfall**	
Code		1WMBLR1	2WMBLR1	1WMUES1	2WMUES1	1WMPO1	2WMPO1
Date		8/9/01	2/2/02	8/9/01	2/2/02	8/9/01	2/2/02
Time		2:14 PM	3:55 PM	6:13 PM	3:05 PM	5:40 PM	2:05 PM
Cond.	µS/cm	220	140	248	150	234	150
Temp.	^{o}C	17.7		20.6	6.9	20.4	6.9
pH		7.5	7.5	7.5	7.5	7.5	7.6
DO	mg/L		7	5	7	6	8
Alkalinity	mg/L	91	98	99	93	94	102
Hardness	mg/L	108	111	122	112	108	116
DOC	mg/L	0.92	1.44	1.42	1.97	1.34	2.08
TSS	mg/L	0.488	2.500	30.500	14.318	5.000	18.043
TDS	mg/L	133	144	147	146	137	152
SS	mL/L	0.1	0.1	0.1	0.1	0.0	0.1
Nitrate	mg/L	1.174	1.045	1.056	0.953	0.915	0.937
Nitrite	mg/L	0.069	0.042	0.083	0.015	0.106	0.061
Ammonia	mg/L	0.059	0.131	0.216	0.142	0.652	0.302
TKN	mg/L	0.826	0.189	1.489	0.365	1.842	0.288
FTKN	mg/L	0.763	0.000	0.779	0.000	0.469	0.172
Ortho-P	mg/L	0.067	0.098	0.142	0.092	0.097	0.107
FTP	mg/L	0.000	0.000	0.000	0.000	0.000	0.000
TP	mg/L	0.075	0.000	0.280	0.000	0.168	0.000

Wallace Mill Stream BI=Upper Benthic Sampling Site; ES=Entering Stream; EI=Lower Benthic Sampling Site (End of Impairment)							
		Upper Benthic		**Entering Stream**		**Lower Benthic**	
Code		1WMBI1	2WMBI1	1WMES1	2WMES1	1WMEI1	2WMEI1
Date		8/9/01	2/2/02	8/9/01	2/2/02	8/9/01	2/2/02
Time		4:25 PM	1:30 PM	3:38 PM	4:40 PM	3:00 PM	11:45 AM
Cond.	µS/cm	234	150	258	170	232	150
Temp.	^{o}C	20.0	9.9	26.5		28.6	8.4
pH		7.7	7.6	7.9	7.6	8.3	7.9
DO	mg/L	7	8	7	7	7	9
Alkalinity	mg/L	90	99	110	115	91	96
Hardness	mg/L	109	113	125	132	115	113
DOC	mg/L	1.27	2.15	1.45	1.68	1.53	2.08
TSS	mg/L	11.264	8.367	20.250	18.085	9.524	31.304
TDS	mg/L	137	147	154	166	157	144
SS	mL/L	0.1	0.1	0.1	0.1	0.1	0.2
Nitrate	mg/L	1.447	1.305	0.270	0.273	1.519	1.369
Nitrite	mg/L	0.170	0.062	0.002	0.000	0.114	0.052
Ammonia	mg/L	0.474	0.503	0.000	0.000	0.000	0.256
TKN	mg/L	1.382	0.806	0.816	0.036	1.143	0.746
FTKN	mg/L	1.130	0.373	0.321	0.049	0.472	0.126
Ortho-P	mg/L	0.093	0.111	0.000	0.000	0.076	0.077
FTP	mg/L	0.000	0.000	0.000	0.000	0.000	0.000
TP	mg/L	0.216	0.000	0.000	0.000	0.080	0.000

Water Sample Analysis Results for Montebello Spring Branch

(See Appendix G for detection limits)

Montebello Spring Branch
Trout Farm Headwaters

Code		MH1	MH2	MH3	4MH1	5MH1	6MH1	7MH1	8MH1
Date		7/18/01	7/18/01	7/19/01	8/14/01	8/15/01	8/15/01	8/15/01	1/29/02
Time		2:40 PM	9:20 PM	9:10 AM	11:36 AM	9:25 AM	1:29 PM	8:53 PM	10:12 AM
Cond.	µS/cm	11	13	13	18		16	19	10
Temp.	^{o}C	12.5	12.5	12.3	13.4	13.3	13.3	13.6	8.1
pH		6.4	6.8	6.3	6.1	6.1	6.1	6.1	6.3
DO	mg/L	8	7	8	8	9	9	7	8
Alkalinity	mg/L	3	4	4	5	5	5	4	2
Hardness	mg/L	2	2	2	5	5	5	5	4
DOC	mg/L	2.14	2.31	2.17	1.46	1.56	1.20	0.93	0.85
TSS	mg/L	0.000	0.000	0.000	0.449	0.000	0.889	0.000	0.000
TDS	mg/L	8	8	8	11	11	11	11	21
SS	mL/L	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitrate	mg/L	0.185	0.186	0.180	0.172	0.189	0.179	0.182	0.162
Nitrite	mg/L	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ammonia	mg/L	0.492	0.527	0.476	0.000	0.038	0.000	0.000	0.000
TKN	mg/L	1.183	0.866	0.919	0.834	0.464	0.404	0.659	0.000
FTKN	mg/L	0.093	0.168	0.117	0.000	0.000	0.000	0.000	0.000
Ortho-P	mg/L	0.000	0.000	0.000	0.000	0.033	0.030	0.029	0.000
FTP	mg/L	0.029	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TP	mg/L	0.117	0.111	0.053	0.000	0.030	0.044	0.039	0.000

Montebello Spring Branch
Trout Farm Outfall-No Activity

Code		MNA1	MNA2	MNA3	4MNA1	5MNA1	6MNA1	7MNA1	8MNA1
Date		7/18/01	7/18/01	7/18/01	8/14/01	8/15/01	8/15/01	8/15/01	1/29/02
Time		3:10 PM	9:43 PM	7:40 AM	7:47 AM	7:45 AM	1:45 PM	9:08 PM	11:40 AM
Cond.	µS/cm	25	28	26	27	12	28	29	20
Temp.	^{o}C	13.9	13.6	13.1	14.2	13.4	15.3	15.3	9.0
pH		6.9	7.0	6.7	6.5	6.8	7.2	6.9	6.6
DO	mg/L	9	7	7	7	7	7	7	7
Alkalinity	mg/L	9	10	9	2	2	0	0	8
Hardness	mg/L	3	3	3	7	6	6	6	5
DOC	mg/L	3.13	3.48	3.60	1.87	0.86	1.36	1.29	2.40
TSS	mg/L	0.294	0.000	4.412	2.143	2.273	0.706	0.222	3.878
TDS	mg/L	20	21	20	16	16	16	16	23
SS	mL/L	0.1	0.0	0.2	0.1	0.0	0.0	0.0	0.1
Nitrate	mg/L	0.310	0.305	0.284	0.386	0.366	0.395	0.388	0.271
Nitrite	mg/L	0.018	0.018	0.016	0.022	0.014	0.017	0.021	0.000
Ammonia	mg/L	1.671	1.907	1.597	0.595	0.743	0.871	1.102	1.163
TKN	mg/L	2.337	2.611	2.156	0.743	1.063	0.677	0.456	1.740
FTKN	mg/L	0.717	0.943	0.849	0.245	0.076	0.124	0.189	1.162
Ortho-P	mg/L	0.069	0.057	0.125	0.066	0.091	0.107	0.000	0.163
FTP	mg/L	0.036	0.005	0.089	0.000	0.000	0.000	0.000	0.000
TP	mg/L	0.279	0.231	0.329	0.096	0.189	0.208	0.189	0.000

Montebello Spring Branch								
Trout Farm Outfall-Pre-cleaning Feeding								
Began feeding at 7:56 a.m. and stopped at 8:05 a.m.								
Code			1MF1	1MF2	1MF3	1MF4	1MF5	1MF6
Date			7/19/01	7/19/01	7/19/01	7/19/01	7/19/01	7/19/01
Time			8:15 AM	8:21 AM	8:25 AM	8:29 AM		8:44 AM
Cond.	µS/cm	27						
Temp.	^oC	13.2						
pH		6.8						
DO	mg/L	8						
Alkalinity	mg/L		9	9	8	8	9	9
Hardness	mg/L		3	3	4	3	3	4
DOC	mg/L		2.99	3.05	3.47	3.24	3.71	2.81
TSS	mg/L		1.250	2.059	1.449	2.581	3.030	0.000
TDS	mg/L		19	21	20	20	21	21
SS	mL/L		0.1	0.1	0.1	0.0	0.0	0.1
Nitrate	mg/L		0.283	0.282	0.280	0.285	0.282	0.285
Nitrite	mg/L		0.015	0.015	0.020	0.013	0.019	0.019
Ammonia	mg/L		1.421	1.510	1.554	1.546	1.410	1.404
TKN	mg/L		2.054	2.021	2.140	2.225	2.035	2.315
FTKN	mg/L		0.639	0.853	0.853	0.733	0.621	0.622
Ortho-P	mg/L		0.149	0.150	0.166	0.177	0.156	0.187
FTP	mg/L		0.092	0.059	0.099	0.130	0.098	0.121
TP	mg/L		0.286	0.309	0.310	0.287	0.300	0.309

Montebello Spring Branch									
Trout Farm Outfall-Pre-cleaning Feeding									
Code			2MF1	2MF2	2MF3	2MF4	2MF5	2MF6	2MF7
Date			7/19/01	7/19/01	7/19/01	7/19/01	7/19/01	7/19/01	7/19/01
Time			11:15 AM	11:20 AM	11:25 AM	11:30 AM	11:35 AM	11:40 AM	11:50 AM
Cond.	µS/cm	26							
Temp.	^oC	13.4							
pH		7.4							
DO	mg/L	8							
Alkalinity	mg/L		9	8	9	9	8	9	9
Hardness	mg/L		4	4	4	4	3	4	3
DOC	mg/L		3.14	2.79	2.99	2.67	3.47	3.22	3.52
TSS	mg/L		1.176	0.000	3.385	4.242	4.545	5.507	5.373
TDS	mg/L		21	21	21	21	21	21	21
SS	mL/L		0.0	0.1	0.0	0.0	0.1	0.1	0.0
Nitrate	mg/L		0.281	0.285	0.283	0.289	0.291	0.286	0.288
Nitrite	mg/L		0.014	0.017	0.019	0.015	0.018	0.023	0.025
Ammonia	mg/L		1.401	1.494	1.515	1.353	1.507	1.499	1.559
TKN	mg/L		2.143	2.309	2.406	2.207	2.510	2.526	2.845
FTKN	mg/L		0.748	0.800	0.810	0.880	0.823	1.355	0.888
Ortho-P	mg/L		0.198	0.197	0.203	0.181	0.196	0.207	0.189
FTP	mg/L		0.122	0.179	0.174	0.143	0.186	0.149	0.154
TP	mg/L		0.336	0.316	0.349	0.334	0.316	0.327	0.319

Montebello Spring Branch										
Trout Farm Outfall-Pre-cleaning Harvesting										
Simulated harvest in lowest raceway. Began at 8:45 a.m. and stopped at 9:00 a.m.										
Code			MHR1	MHR2	MHR3	MHR4	MHR5	MHR6	MHR7	MHR8
Date			7/19/01	7/19/01	7/19/01	7/19/01	7/19/01	7/19/01	7/19/01	7/19/01
Time				9:00 AM	9:06 AM	9:12 AM	9:15 AM	9:30 AM	9:44 AM	10:00 AM
Cond.	µS/cm	27								
Temp.	^{o}C	13.2								
pH		7.2								
DO	mg/L	7								
Alkalinity	mg/L		9	9	10	9	10	10	10	10
Hardness	mg/L		4	3	3	3	3	3	4	4
DOC	mg/L		3.25	3.93	3.92	3.59	3.52	3.16	3.50	3.87
TSS	mg/L		0.290	1.538	0.882	0.000	1.231	0.000	0.615	0.000
TDS	mg/L		21	21	21	21	22	22	21	21
SS	mL/L		0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.1
Nitrate	mg/L		0.293	0.296	0.295	0.298	0.303	0.309	0.300	0.314
Nitrite	mg/L		0.026	0.029	0.029	0.034	0.035	0.030	0.039	0.044
Ammonia	mg/L		1.422	1.609	1.667	1.510	1.533	1.604	1.507	1.517
TKN	mg/L		2.217	2.181	2.436	2.312	2.416	2.541	2.180	2.043
FTKN	mg/L		0.758	0.862	0.867	1.025	0.835	0.889	0.821	0.958
Ortho-P	mg/L		0.180	0.172	0.146	0.136	0.166	0.192	0.180	0.170
FTP	mg/L		0.137	0.133	0.129	0.133	0.151	0.155	0.178	0.131
TP	mg/L		0.307	0.290	0.300	0.276	0.310	0.293	0.313	0.329

Montebello Spring Branch								
Trout Farm Outfall-Pre-Cleaning Feeding								
Code			3MF1	3MF2	3MF3	3MF4	3MF5	3MF6
Date			8/14/01	8/14/01	8/14/01	8/14/01	8/14/01	8/14/01
Time			8:29 AM	8:34 AM	8:39 AM	8:44 AM	8:49 AM	8:54 AM
Cond.	µS/cm	27						
Temp.	^{o}C	14.2						
pH		6.7						
DO	mg/L	7						
Alkalinity	mg/L		2	3	2	2	2	2
Hardness	mg/L		6	7	7	7	6	6
DOC	mg/L		1.81	1.63	1.62	1.60	1.44	1.56
TSS	mg/L		0.674	0.920	0.674	0.899	1.149	4.138
TDS	mg/L		16	17	16	16	16	17
SS	mL/L		0.0	0.0	0.0	0.0	0.0	0.0
Nitrate	mg/L		0.380	0.379	0.391	0.392	0.392	0.392
Nitrite	mg/L		0.023	0.020	0.020	0.018	0.018	0.018
Ammonia	mg/L		0.644	0.612	0.581	0.591	0.649	0.656
TKN	mg/L		0.703	0.886	0.447	0.516	0.583	0.509
FTKN	mg/L		0.221	0.007	0.074	0.165	0.030	0.266
Ortho-P	mg/L		0.072	0.076	0.071	0.076	0.072	0.070
FTP	mg/L		0.000	0.000	0.034	0.000	0.000	0.000
TP	mg/L		0.048	0.058	0.428	0.279	0.254	0.233

Montebello Spring Branch
Trout Farm Outfall-Post-cleaning Feeding
Began feeding at 8:40 a.m and stopped at 9:00 a.m.

Code			4MF1	4MF2	4MF3	4MF4	4MF5	4MF6
Date			8/15/01	8/15/01	8/15/01	8/15/01	8/15/01	8/15/01
Time			9:07 AM	9:12 AM	9:16 AM	9:19 AM	9:30 AM	9:40 AM
Cond.	µS/cm							
Temp.	^{o}C	13.7						
pH		7.0						
DO	mg/L	7						
Alkalinity	mg/L		1	1	2	2	2	2
Hardness	mg/L		6	6	7	7	7	7
DOC	mg/L		1.31	1.44	1.28	1.40	1.33	1.38
TSS	mg/L		0.460	0.460	1.379	0.899	0.667	1.220
TDS	mg/L		16	16	16	16	16	16
SS	mL/L		0.0	0.0	0.0	0.1	0.0	0.0
Nitrate	mg/L		0.374	0.368	0.377	0.369	0.376	0.382
Nitrite	mg/L		0.013	0.011	0.012	0.011	0.012	0.011
Ammonia	mg/L		0.737	0.697	0.737	0.729	0.744	0.754
TKN	mg/L		0.536	0.627	0.629	0.876	0.866	0.966
FTKN	mg/L		0.000	0.000	0.148	0.000	0.000	0.000
Ortho-P	mg/L		0.110	0.110	0.113	0.115	0.120	0.129
FTP	mg/L		0.000	0.000	0.000	0.000	0.000	0.000
TP	mg/L		0.194	0.223	0.221	0.231	0.218	0.195

Montebello Spring Branch
Trout Farm Outfall-Post-cleaning Feeding
Began feeding at 8:14 a.m. and stopped at 8:35 a.m.

Code			5MF1	5MF2	5MF3	5MF4	5MF5	5MF6	5MF7
Date			8/16/01	8/16/01	8/16/01	8/16/01	8/16/01	8/16/01	8/16/01
Time			8:05 AM	8:10 AM	8:21 AM	8:26 AM	8:30 AM	8:40 AM	8:50 AM
Cond.	µS/cm	28							
Temp.	^{o}C	14.2							
pH		6.7							
DO	mg/L	7							
Alkalinity	mg/L		1	2	1	1	2	2	2
Hardness	mg/L		7	7	7	7	7	7	7
DOC	mg/L		1.39	1.35	1.34	1.33	1.39	1.36	1.50
TSS	mg/L		0.444	0.930	1.364	0.706	5.000	1.839	1.136
TDS	mg/L		16	16	16	16	17	16	16
SS	mL/L		0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitrate	mg/L		0.376	0.385	0.383	0.381	0.386	0.390	0.381
Nitrite	mg/L		0.014	0.016	0.014	0.014	0.016	0.016	0.022
Ammonia	mg/L		0.789	0.774	0.732	0.792	0.788	0.956	0.805
TKN	mg/L		0.629	0.573	1.137	0.719	0.824	1.041	0.895
FTKN	mg/L		0.805	0.311	0.414	0.503	0.443	0.269	0.261
Ortho-P	mg/L		0.130	0.127	0.119	0.129	0.145	0.132	0.140
FTP	mg/L		0.000	0.000	0.000	0.000	0.000	0.000	0.000
TP	mg/L		0.188	0.226	0.244	0.205	0.252	0.218	0.250

Montebello Spring Branch - Trout Farm Outfall-Cleaning Main Settling Basin								
Started at 9:44 a.m. Took 5 to 8 minutes to fill tank. Took 15-20 minutes to empty tank (land applied on nearby field). At 11:18 a.m moved to upper sediment basin. Stopped at 11:22 a.m.								
Code			1MCL1	1MCL2	1MCL3	1MCL4	1MCL5	1MCL6
Date			8/14/01	8/14/01	8/14/01	8/14/01	8/14/01	8/14/01
Time			9:45 AM	10:00 AM	10:10 AM	10:37 AM	10:41 AM	10:55 AM
Cond.	µS/cm	28						
Temp.	^{o}C	16.0						
pH		6.9						
DO	mg/L	7						
Alkalinity	mg/L		2	1	2	2	2	2
Hardness	mg/L		7	7	7	7	7	7
DOC	mg/L		1.69	1.55	1.63	1.62	1.51	1.85
TSS	mg/L		2.093	2.921	1.882	5.057	7.556	1.818
TDS	mg/L		17	17	16	16	16	16
SS	mL/L		0.1	0.1	0.1	0.1	0.3	0.1
Nitrate	mg/L		0.384	0.403	0.390	0.393	0.395	0.390
Nitrite	mg/L		0.018	0.020	0.022	0.014	0.020	0.017
Ammonia	mg/L		0.652	0.724	0.608	0.614	0.640	0.668
TKN	mg/L		0.831	0.624	0.500	0.709	0.759	0.751
FTKN	mg/L		0.245	0.163	0.083	0.292	0.243	0.127
Ortho-P	mg/L		0.087	0.085	0.081	0.083	0.087	0.099
FTP	mg/L		0.000	0.000	0.000	0.000	0.000	0.000
TP	mg/L		0.259	0.276	0.215	0.263	0.269	0.242

Montebello Spring Branch - Trout Farm Outfall-Cleaning Main Settling Basin								
Began cleaning again at 1:26 p.m. Finished cleaning at 1:53 p.m.								
Code			1MCL7	1MCL8	1MCL9	1MCL10	1MCL11	1MCL12
Date			8/14/01	8/14/01	8/14/01	8/14/01	8/14/01	8/14/01
Time			11:23 AM	1:16 PM	1:32 PM	1:45 PM	2:03 PM	2:13 PM
Cond.	µS/cm	28						
Temp.	^{o}C	16.0						
pH		6.9						
DO	mg/L	7						
Alkalinity	mg/L		2	1	1	0	1	1
Hardness	mg/L		7	7	7	6	6	6
DOC	mg/L		1.76	1.71	1.84	1.58	1.74	1.52
TSS	mg/L		2.558	1.573	2.759	8.090	5.581	5.227
TDS	mg/L		16	16	16	16	16	16
SS	mL/L		0.0	0.0	0.0	0.1	0.2	0.1
Nitrate	mg/L		0.396	0.412	0.418	0.420	0.418	0.412
Nitrite	mg/L		0.021	0.014	0.021	0.021	0.020	0.020
Ammonia	mg/L		0.679	0.832	0.868	0.852	0.872	0.882
TKN	mg/L		0.579	0.680	0.645	0.698	0.587	0.850
FTKN	mg/L		0.025	0.080	0.234	0.102	0.112	0.000
Ortho-P	mg/L		0.092	0.099	0.093	0.094	0.095	0.090
FTP	mg/L		0.000	0.000	0.000	0.000	0.000	0.000
TP	mg/L		0.214	0.209	0.249	0.261	0.227	0.202

Montebello Spring Branch							
Trout Farm Outfall-Post-cleaning Harvesting							
Simulated harvest began at 8:15 a.m. and stopped at 8:30 a.m.							
Code		2MHR1	2MHR2	2MHR3	2MHR4	2MHR5	2MHR6
Date		8/15/01	8/15/01	8/15/01	8/15/01	8/15/01	8/15/01
Time		8:32 AM	8:37 AM	8:42 AM	8:48 AM	8:55 AM	8:59 AM
Cond.	µS/cm						
Temp.	^{o}C						
pH							
DO	mg/L						
Alkalinity	mg/L	2	1	2	2	2	2
Hardness	mg/L	7	6	7	7	7	7
DOC	mg/L	1.33	1.27	1.26	1.14	1.28	1.18
TSS	mg/L	1.319	0.000	1.099	0.714	0.444	0.698
TDS	mg/L	16	16	16	16	16	16
SS	mL/L	0.0	0.0	0.0	0.0	0.0	0.0
Nitrate	mg/L	0.384	0.389	0.398	0.403	0.400	0.402
Nitrite	mg/L	0.024	0.026	0.029	0.036	0.014	0.015
Ammonia	mg/L	0.794	0.776	0.721	0.900	0.599	0.745
TKN	mg/L	0.506	0.655	0.525	0.684	0.629	0.694
FTKN	mg/L	0.160	0.208	0.350	0.000	0.474	0.345
Ortho-P	mg/L	0.125	0.121	0.131	0.124	0.078	0.097
FTP	mg/L	0.000	0.000	0.000	0.000	0.000	0.000
TP	mg/L	0.198	0.201	0.203	0.169	0.216	0.250

Montebello Spring Branch				
End of Raceway-Post-cleaning Harvesting				
Code		2MHR7	2MHR8	2MHR9
Date		8/15/01	8/15/01	8/15/01
Time		8:18 AM	8:25 AM	8:30 AM
Cond.	µS/cm			
Temp.	^{o}C			
pH				
DO	mg/L			
Alkalinity	mg/L	4	3	3
Hardness	mg/L	8	6	7
DOC	mg/L	1.79	1.65	1.30
TSS	mg/L	18.621	11.011	8.736
TDS	mg/L	17	19	16
SS	mL/L	0.1	1.0	0.1
Nitrate	mg/L	0.256	0.268	0.271
Nitrite	mg/L	0.005	0.012	0.016
Ammonia	mg/L	0.439	0.505	0.620
TKN	mg/L	1.001	0.904	0.786
FTKN	mg/L	0.787	0.994	0.490
Ortho-P	mg/L	0.132	0.106	0.104
FTP	mg/L	0.022	0.000	0.000
TP	mg/L	0.460	0.329	0.318

Solids Samples from Trout Facilities located on Montebello Spring Branch, Orndorff Spring Branch, and Wallace Mill Stream.

(See Appendix G for detection limit)

Stream Segment	Sample Location	Sample Date	% Organic Content
Montebello Spring Branch	Settling Basin-Below Raceways	7/19/2001	50
Montebello Spring Branch	Settling Basin-Below Raceways	7/19/2001	55
Montebello Spring Branch	Settling Basin-Below Raceways	7/19/2001	10
Montebello Spring Branch	Settling Basin-Below Raceways	7/19/2001	50
Montebello Spring Branch	Settling Basin-Below Raceways	7/19/2001	44
Montebello Spring Branch	Settling Basin-Below Raceways	7/19/2001	49
Montebello Spring Branch	Settling Basin-Below Raceways	7/19/2001	53
Montebello Spring Branch	Settling Basin-Below Raceways	7/19/2001	56
Orndorff Spring Branch	Sediment Trap-Lower Raceway	7/26/2001	78
Orndorff Spring Branch	Sediment Trap-Lower Raceway	7/26/2001	75
Orndorff Spring Branch	Sediment Trap-Lower Raceway	7/26/2001	78
Orndorff Spring Branch	Sediment Trap-Lower Raceway	7/26/2001	73
Orndorff Spring Branch	Sediment Trap-Middle Raceway	7/26/2001	62
Orndorff Spring Branch	Sediment Trap-Upper Raceway	7/26/2001	74
Orndorff Spring Branch	Sediment Trap-Upper Raceway	7/26/2001	83
Orndorff Spring Branch	Sediment Trap-Upper Raceway	7/26/2001	74
Wallace Mill Stream	Sed. Trap-3rd Raceway, Lower Series	8/10/2001	61
Wallace Mill Stream	Sed. Trap-3rd Raceway, Lower Series	8/10/2001	62
Wallace Mill Stream	Sed. Trap-3rd Raceway, Lower Series	8/10/2001	53
Wallace Mill Stream	Sed. Trap-3rd Raceway, Lower Series	8/10/2001	70
Wallace Mill Stream	Sed. Trap-3rd Raceway, Lower Series	8/10/2001	71
Wallace Mill Stream	Sed. Trap-3rd Raceway, Lower Series	8/10/2001	48
Wallace Mill Stream	Sed. Trap-3rd Raceway, Lower Series	8/10/2001	41
Wallace Mill Stream	Sed. Trap-3rd Raceway, Lower Series	8/10/2001	53
Wallace Mill Stream	Sed. Trap-3rd Raceway, Lower Series	8/10/2001	72
		Average	**60**

APPENDIX I - Revised Universal Soil Loss Equation (RUSLE)

Background
The stream segments considered in this TMDL report are short (0.02-0.8 miles) and the areas for the impaired watersheds range from 10 acres (the smallest) to over 1,400 acres (the largest). Conventional models usually used to determine nonpoint source loads are too complex and not applicable to these small watersheds. Upon review of modeling techniques it was determined that the Revised Universal Soil Loss Equation (RUSLE) can adequately estimate sediment load to streams in small watersheds. The EPA Region 4 has applied the RUSLE to TMDL assessment in watersheds up to 10,000 acres in Georgia (Greenfield 2002). Additional information about RUSLE can be found on the U.S. Department of Agriculture-Agricultural Research Service website: www.sedlab.olemiss.edu/rusle.

Revised Universal Soil Loss Equation (RUSLE)

RUSLE is a soil loss estimation method that originates from the Universal Soil Loss Equation (USLE) that was developed in the 1950's. Using the RUSLE, different areas within a watershed can yield different average annual soil loss owing to the differences in RUSLE parameters for those areas. The RUSLE estimates total Average Annual Soil Loss per acre (A). To estimate the Average Total Soil Loss for a given area, A is multiplied by the acreage of the area.

RUSLE is defined by the following equation:

$A = R\ K\ LS\ C\ P$

The RUSLE parameters are described below.

R factor: The R factor represents the erosive potential (erosivity) caused by the amount and intensity of precipitation and other climatic factors at a particular location. Weather records are used to determine an average annual value of R.

K factor: The K factor accounts for the inherent erodibility of a soil, based on unique structural and compositional properties. The K factor is affected by:

- the detachability of the soil,
- infiltration and runoff rates,
- the transportability of the sediment eroded from the soil,
- soil texture,
- organic matter,
- soil structure, and
- the permeability of the soil profile.

Empirical values of K for a given soil type are derived from extensive measurements on unit plot conditions.

LS factor: The L and S factors account for the shape and steepness of the slope and its effects on soil erosion and sediment production. The LS factor represents the combined effects on erosion caused by surface runoff and erosion caused primarily by raindrop impact. According to soil erosion theory and numerous field observations, erosion increases with slope steepness and is significantly affected by the shape of the slope. Soil loss is greatest on slopes that become steeper near the bottom and least on slopes where the steep section is at the upper end of the slope.

C factor: The C factor represents the impacts of land use and land cover and has the most significant impact on soil erosion rates. It is the easiest factor to change and one of the hardest to estimate. The C factor is influenced by:

- cover above but not in contact with the soil surface,
- cover directly in contact with the soil surface,
- roughness of the soil surface,
- time since last mechanical disturbance,
- amount of live and dead roots in the soil, and
- organic material that has been incorporated into the soil.

The variables influencing the C factor change throughout the year. Consequently, the factor is calculated as an average annual value, weighted according to the variation of rainfall erosivity over the year.

P factor: Management practices, such as contour crops, strip crops, terraces, sediment basins, grass hedges, silt fences, and straw bales, are represented by the supporting practice (P) factor. Supporting practices reduce erosion by directing runoff around, instead of directly down, the slope, or slowing it to promote deposition of sediment along the slope.

Using the riparian zone of Ingleside Spring Branch as an example, the Average Annual Soil Loss value, A, for the different land uses was calculated by multiplying the respective RUSLE factors: R, K, LS, C, and P (See Table I.1). The annual A value for the pasture/grassy field area of the Ingleside Spring Branch riparian zone (300 feet on either side of the stream) was 0.41 tons per acre, and the annual A value for the road in the Ingleside Spring Branch riparian zone was 3.54 tons per acre. Multiplying these values by their respective area yielded Total Soil Loss values of 4.68 tons per year for the pasture/grassy field area and 2.41 tons per year for the road area.

Table I.1 Area, RUSLE factors (R, K, LS, C, and P), Average Annual Soil Loss (A), and Total Soil Loss for the land uses within the Ingleside Spring Branch riparian zone.

	Area	**R**	**K**	**LS**	**C**	**P**	**A**	**Soil Loss**
Ingleside Spring Branch	(acres)						(tons/acre-yr)	(tons/yr)
Pasture/Grassy Field	11.38	135	0.51	1.99	0.003	1	0.41	4.68
Road	0.68	135	0.50	1.75	0.030	1	3.54	2.41

Sediment Yield

Sediment Yields (tons per year) were calculated by multiplying the Total Soil Loss (tons per year) by the Sediment Delivery Ratio (SDR). The SDR of small areas is assumed to be 90 percent (0.9), meaning that 90 percent of the available sediment in the area makes its way to the stream. For example, within the Ingleside Spring Branch riparian zone, the product of the Total Soil Loss for the pasture/grassy field (4.68 tons per year) and SDR (0.9) gives a Sediment Yield of 4.21 tons per year. The Sediment Yield for the road was 2.17 tons per year (2.41 x 0.9). The sum of the two Sediment Yields gives the total Sediment Yield (6.38 tons per year) for the Ingleside Spring Branch riparian zone.

Organic Matter Yield

For the nonpoint source runoff, an Organic Matter Content of 5 percent was used in the TMDL calculations. Organic Matter Yield (tons per year) was obtained from Sediment Yield (tons per year) times the percent Organic Matter Content. For example at Ingleside Spring Branch, the Sediment Yield of 6.38 tons per year was multiplied by 0.05 to give an Organic Matter Yield of approximately 0.32 tons per year (638 pounds per year).

RUSLE APPLICATION

For this TMDL report, the Average Annual Soil Loss and Sediment Yields were estimated for the 300-foot riparian area on each side of the impaired segments. Watershed and riparian area delineation techniques are described in Appendix E.

The database to develop soil loss estimates for this project was obtained from a variety of online sources and printed references. The following sections describe the data sets used for each factor in the RUSLE calculation, including their online locations and any operations that had to be performed on the data.

Data Sources

R values

R values were taken from the Natural Resources Conservation Service (NRCS) RUSLE handbook for Virginia. A basic rectangular polygon covering the entire study area was drawn to represent a uniform R value across the study area.

K values

K values are related to soil properties. Soils data were obtained from the United States Department of Agriculture Soil Survey Geographic (SSURGO) database and available county soil surveys. Polygons representing the different soil types in the area were linked to a database file containing K values for each of the soil types.

LS values

Values for the LS factor(s) were calculated using a method developed by Perdue University (http://pasture.ecn.purdue.edu/~engelb/agen526/gisrusle/gisrusle.html). In order to effectively apply this method to the study sites, some datasets had to be modified. The DEM grids were resampled to a 5-m grid cell size to account for proximity of streams within the basins and merged to provide a continuous coverage throughout the area of interest. Also, the DEM grids had to be merged at sites where the watershed was likely to cover portions of multiple USGS topo quads.

C values

The USGS Land Use Land Cover (LULC) data and tables for C values given in Novotny and Olem (1994) were used to make initial estimates of C values. These values were verified in the field and corrected when necessary. The LUCL data are derived from thematic overlays registered to 1:250,000-scale base maps and a limited number of 1:100,000-scale base maps. The data is available through the USGS Geospatial Data & Information Products website (http://mapping.usgs.gov/www/products/1product.html#digital) (Table I.2).

P values

There were no land use management practices in the existing land uses for to this TMDL study. Therefore, P = 1 was used. For Best Management Practices (BMPs), a P value of less than 1 was assigned based on professional judgment.

Table I.2. Cover (C) factors estimated from the USGS LULC database

Cover (C) factors used in the RUSLE

Land Use	USGS Level II code	Estimated C	Reason
Residential	11	0.003	permanent pasture 85-100% grass cover
Commercial and Services	12	0.04	permanent pasture 60% grass cover
Industrial	13	0.04	permanent pasture 60% grass cover
Trans,Comm,Util	14	0.03	Asphalt emulsion 12m^3/ha
Indust & Commerc Cmplxs	15	0.09	permanent pasture 60% weed cover
Mxd Urban or Built-Up	16	0.01	permanent pasture 80% grass cover
Other Urban or Built-Up	17	0.01	permanent pasture 80% grass cover - subject to change
Pasture/cropland	21	0.8	worst case - shortly after seeding prior to harvesting
Orch,Grov,Vnyrd,Nurs,Orn	22	0.003	Managed woodland 40-75% canopy
Confined Feeding Ops	23	1	Construction Site - no mulch or seeding
Other Agricultural Land	24	0.2	average for crops in main growing season - subject to change
Herbaceous	31	0.09	permanent pasture 60% weed cover
Shrub & Brush Rangeland	32	0.09	permanent pasture 60% weed cover
MixedRng	33	0.09	permanent pasture 60% weed cover
Deciduous Forest Land	41	0.001	managed woodland 75-100% canopy
Evergreen Forest Land	42	0.002	managed woodland 40-75% canopy
Mixed Forest Land	43	0.015	average Deciduous and Evergreen
Streams and Canals	51	1	cannot contribute
Lakes	52	1	cannot contribute
Reservoirs	53	1	cannot contribute
Bays	54	1	cannot contribute
Forested Wetland	61	0.001	Managed woodland 75-100% canopy
NonForested Wetland	62	0.003	permanent pasture 85-100% grass cover
DryFlats	71		not found near study area
Beaches	72		not found near study area
OtherSandy	73		not found near study area
ExposedRock	74	0.05	Construction Site - Crushed Stone
Strip Mines	75	0.05	Construction Site - Crushed Stone
Transitional Areas	76	0.025	low density growth meadow
MixedBarren	77		not found near study area
ShrubTundra	81		not found near study area
HerbaceousTundra	82		not found near study area
BareTundra	83		not found near study area
WetTundra	84		not found near study area
MixedTundra	85		not found near study area
PerennialSnow	91		not found near study area
Glacier	92		not found near study area

Table I.3 shows a summary of input data used to calculate the existing loads of for each riparian area of the impaired streams. For calculating Sediment Yield from the riparian areas, the SDR value was set to 0.9 because a large majority of the material from the riparian area is transported to the stream. The percent organic content was set at five percent. The soils for the areas under study are naturally 2.5 percent organic (from soil surveys). An organic content higher than this was used in the TMDL calculations to account for contributions from runoff containing organic matter picked up on the surface (e.g., manure).

Table I.3 Input data used to determine the organic solids loads for nonpoint sources within the riparian area of the impaired streams.

	Area	R	K	LS	C	P	SDR	Organic Matter
COCKRAN SPRING BRANCH								
Pasture	38.10	130	0.34	1.32	0.003	1	0.9	0.05
LACEY SPRING BRANCH								
Pasture/Grassy Field	8.55	130	0.36	1.02	0.003	1	0.9	0.05
Roads	1.61	130	0.32	0.48	0.030	1	0.9	0.05
Roads' Grassy Slopes	5.80	130	0.32	1.04	0.003	1	0.9	0.05
Residential	2.13	130	0.37	1.37	0.003	1	0.9	0.05
ORNDORFF SPRING BRANCH								
Mixed Forest	1.08	135	0.28	0.19	0.003	1	0.9	0.05
Deciduous Forest	1.22	135	0.28	0.40	0.001	1	0.9	0.05
Driveway	0.05	135	0.28	0.05	0.030	1	0.9	0.05
Hayfield	0.05	135	0.28	0.14	0.003	1	0.9	0.05
PHEASANTY RUN								
Upstream								
Grassy Field	21.71	125	0.32	0.59	0.003	1	0.9	0.05
Road/Drive	0.55	125	0.32	2.08	0.030	1	0.9	0.05
Deciduous Forest	1.15	125	0.32	6.26	0.001	1	0.9	0.05
Impaired Section								
Grassy Field	27.10	125	0.39	0.40	0.003	1	0.9	0.05
Deciduous Forest	2.81	125	0.21	0.94	0.001	1	0.9	0.05
WALLACE MILL STREAM								
Pasture/Grassy Field	43.87	130	0.27	1.10	0.003	1	0.9	0.05
Transitional land	7.14	130	0.27	1.10	0.003	1	0.9	0.05
Decdiuous Forest	10.30	130	0.29	2.35	0.001	1	0.9	0.05
Residential yard	2.38	130	0.32	0.89	0.003	1	0.9	0.05
Roads	1.54	130	0.29	0.21	0.030	1	0.9	0.05
MONTEBELLO SPRING BRANCH								
Deciduous Forest	2.59	155	0.24	4.91	0.001	1	0.9	0.05
Road	0.07	155	0.24	5.67	0.030	1	0.9	0.05

APPENDIX J - Survey Questionnaire Sent to the Trout Facilities

Survey for TMDL Study
Virginia Water Resources Research Center
10 Sandy Hall (0444)
Virginia Tech
Blacksburg, VA 24061

Please complete the following survey and return it by February 1, 2002 in the enclosed envelope. If you have questions, contact Jane Walker at 540/231-4159 or at janewalk@vt.edu.

Information obtained from this survey will be used in a TMDL report.
Write **"Confidential"** beside specific questions or sections you wish to be kept confidential.
Survey responders will not be identified in the TMDL report.

Date:
Name of Facility:
Name of Person Completing Survey: (For contact purposes by VWRRC staff only)

PRODUCTION

Description of market: ________ % processed or sold for processing ________ % stocking

Approximate number of fish at facility

Number of fish under 6 inches

Jan________ Feb________ Mar________ Apr________ May________ Jun________

Jul________ Aug________ Sep________ Oct________ Nov________ Dec________

Number of fish between 6-12 inches

Jan________ Feb________ Mar________ Apr________ May________ Jun________

Jul________ Aug________ Sep________ Oct________ Nov________ Dec________

Number of fish 12 inches and larger

Jan________ Feb________ Mar________ Apr________ May________ Jun________

Jul________ Aug________ Sep________ Oct________ Nov________ Dec________

FEED

Total Amount of feed used: __________ (lbs/year)

What is your approximate feed conversion ratio? (lbs of feed used/lbs of fish gained)

Provide the following information for all feed types used.

A.) Feed type:

Floating _______ Sinking ________ Slow Sinking ________

Manufacturer ____________Percent protein in feed _____ Percent fat in feed _____

Amount of this type of feed fed: (lbs/month)

Jan_________ Feb_________ Mar_________ Apr_________ May________ Jun_________

Jul_________ Aug_________ Sep_________ Oct_________ Nov________ Dec_________

B.) Feed type:

Floating _______ Sinking ________ Slow Sinking ________

Manufacturer ____________Percent protein in feed _____ Percent fat in feed _____

Amount of this type of feed fed: (lbs/month)

Jan_________ Feb_________ Mar_________ Apr_________ May________ Jun_________

Jul_________ Aug_________ Sep_________ Oct_________ Nov________ Dec_________

FACILITY ACTIVITIES

Indicate the frequency of the following activities regularly performed at your facility.
Solids build-up removal/Cleaning Frequency: (Cleanings per MONTH)

Jan_________ Feb_________ Mar_________ Apr_________ May________ Jun_________

Jul_________ Aug_________ Sep_________ Oct_________ Nov________ Dec_________

Comment about cleaning:

What do you do with the removed solids?

Harvesting Frequency: (Harvests per MONTH)

Jan________ Feb ________ Mar ________Apr ________ May _______ Jun________

Jul ________ Aug ________Sep ________ Oct ________ Nov _______ Dec ________

Comment about harvesting:

Feeding Frequency: (Feedings per DAY)

<u>Fry/Fingerlings:</u>

Jan________ Feb ________ Mar ________Apr ________ May _______ Jun________

Jul ________ Aug ________Sep ________ Oct ________ Nov _______ Dec ________

<u>Adults:</u>

Jan________ Feb ________ Mar ________Apr ________ May _______ Jun________

Jul ________ Aug ________Sep ________ Oct ________ Nov _______ Dec ________

Comment about feeding:

How many pounds of medicated feed are generally used at the facility in a year's time?

What medicine(s) are incorporated into the feed?

Quantity and type of chemicals used in the production of your trout (Circle unit of measure)

____	Salt	___________ lbs or kg per year
____	Sodium bicarbonate	___________ lbs or kg per year
____	Finquel* MS-222	___________ lbs or kg per year
____	Potassium permanganate	___________ lbs or kg per year
____	Chloramine-T*	___________ lbs or kg per year
____	Formalin	___________ gal or L per year
____	Paracide-F*	___________ gal or L per year
____	Chlorine bleach	___________ gal or L per year
____	Cutrine/Cutrine Plus*	___________quantity _____ per year
____	Other _____________	___________quantity _____ per year

* Brand name

SPRING FLOW

Estimated flow from the spring: (Gallons per Minute--GPM) ___________

Is the spring flow relatively constant throughout the year? Yes _____ No _____

If the spring flow is not constant, estimate the flow from the spring for each month (GPM):

Jan________ Feb ________ Mar ________Apr ________ May _______ Jun________

Jul ________ Aug ________Sep ________ Oct ________ Nov _______ Dec ________

Have you noticed a change in the spring flow in the past five to ten years?

Yes _____ No _____

If yes, please describe the flow change (increased or decreased), estimate the change in flow (GPM), and tell when you noticed this change.

Note any observations about the spring water quality (*e.g.*, turbidity)**.**

FACILITY

Number of raceways/rearing tanks:

Do you foresee the size of your trout operation changing in the next five years?
Yes ____ No _____

If you expect the size of the operation to change, please describe how much you estimate it will change and whether it will grow or become smaller.

Do you foresee the size of your trout operation changing in the next ten years?
Yes ____ No _____

If you expect the size of the operation to change, please describe how much you estimate it will change and whether it will grow or become smaller.

Describe any pre- or post treatment of the water used: (*e.g.*, aeration, settling of waste solids)

Has your facility met its effluent permit limits for the past five to ten years?

Yes _____ No _____

If not, please explain the problem(s) identified and whether or not it continues to be a problem:

IMPAIRED SEGMENT

Has the impaired stream segment below your facility ever been used for the following?
(Circle all that apply)

- Boating
- Drinking water source
- Irrigation
- Recreational fishing (specify the kind of fishing) ____________________
- Swimming
- Wildlife habitat

Which of the circled uses are not possible at the present time because of the designated "aquatic life impairment?" Please explain why, in your opinion, these uses are not currently possible.

Have there been any complaints from land owners/users below the trout farms concerning the water exiting the trout farms? If so, how many complaints and were they resolved?

ADDITIONAL COMMENTS

Include comments about your facility operations, the impaired stream segment, the TMDL, etc.
(Feel free to write on the back of the paper):